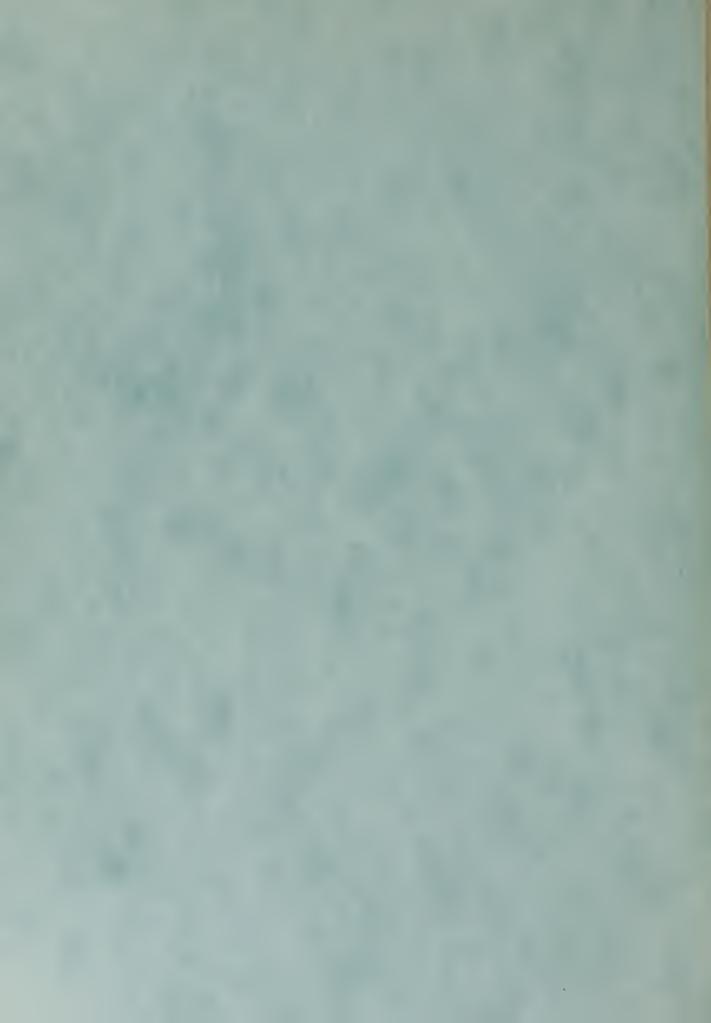
A MULTIVARIATE ANALYSIS OF CERTAIN BIOCHEMICAL COMPONENTS OF EQUINE AND FELINE SERUM SAMPLES AS REPORTED BY AN AUTO-ANALYZER SYSTEM

Ву

Robert Rothnick Jorgensen



United States Naval Postgraduate School



THESIS

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by

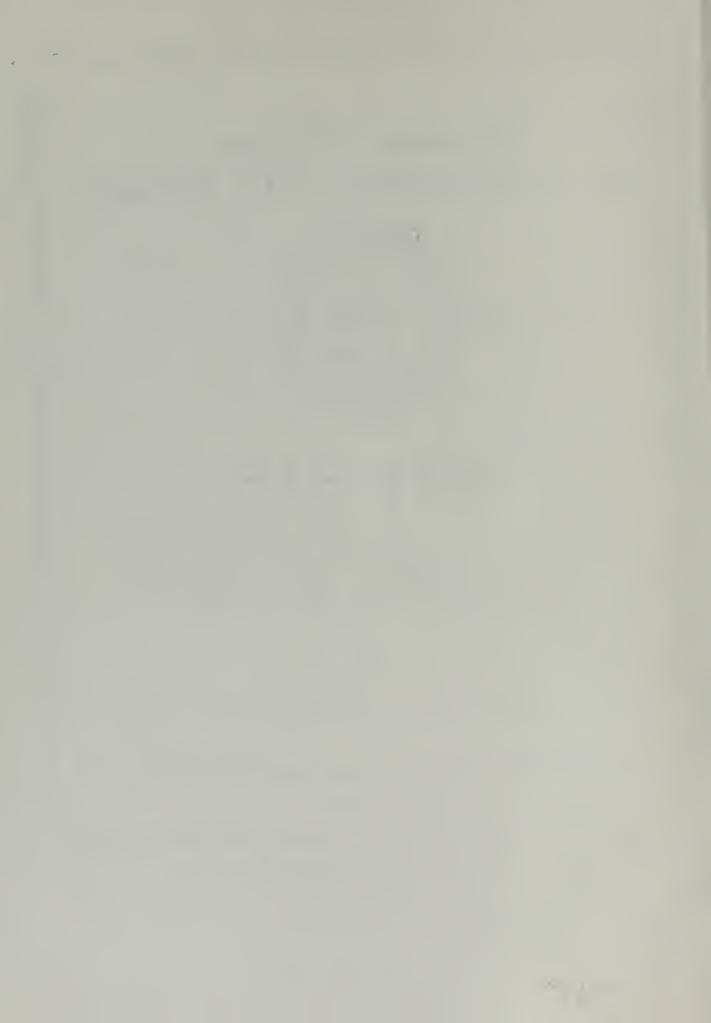
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March 1971

Approved for public release; distribution wilimited.



A Multivariate Analysis of Certain Biochemical Components
of Equine and Feline Serum Samples
as Reported by an Auto-analyzer System

by

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ABSTRACT

This thesis contains a multivariate statistical analysis of the results of an automated analysis of serum samples from the horse and cat. In the horse, 12 biochemical components plus body weight and age are recorded; thus, observations are made on 14 random variables. In the case of the cat there are observations on 13 random variables. Ninety-one (91) pair-wise correlation coefficients are computed from the equine data and 78 pair-wise correlation coefficients are computed from the feline data. Extensive hypothesis testing concerning these correlation coefficients is conducted and the results are presented. A discriminant analysis for 2 groups, male and female, is conducted for each species. In this analysis the vector of sample means of the biochemical components plus body weight and age for males is contrasted with the corresponding vector from females. Tolerance limits for each biochemical component measured are presented for both species.

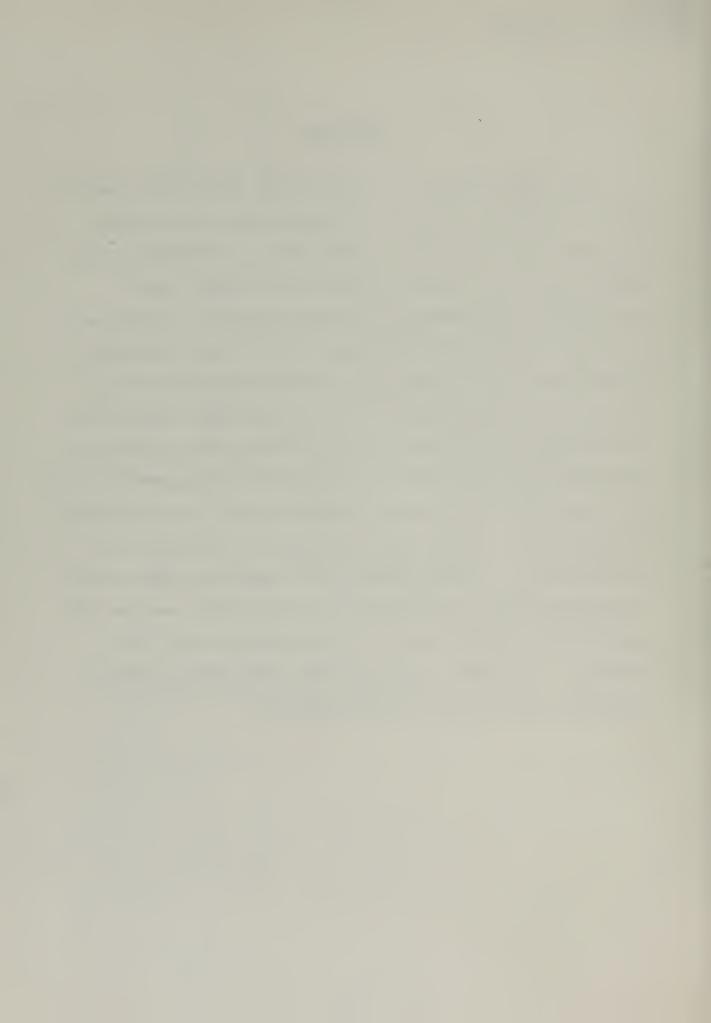


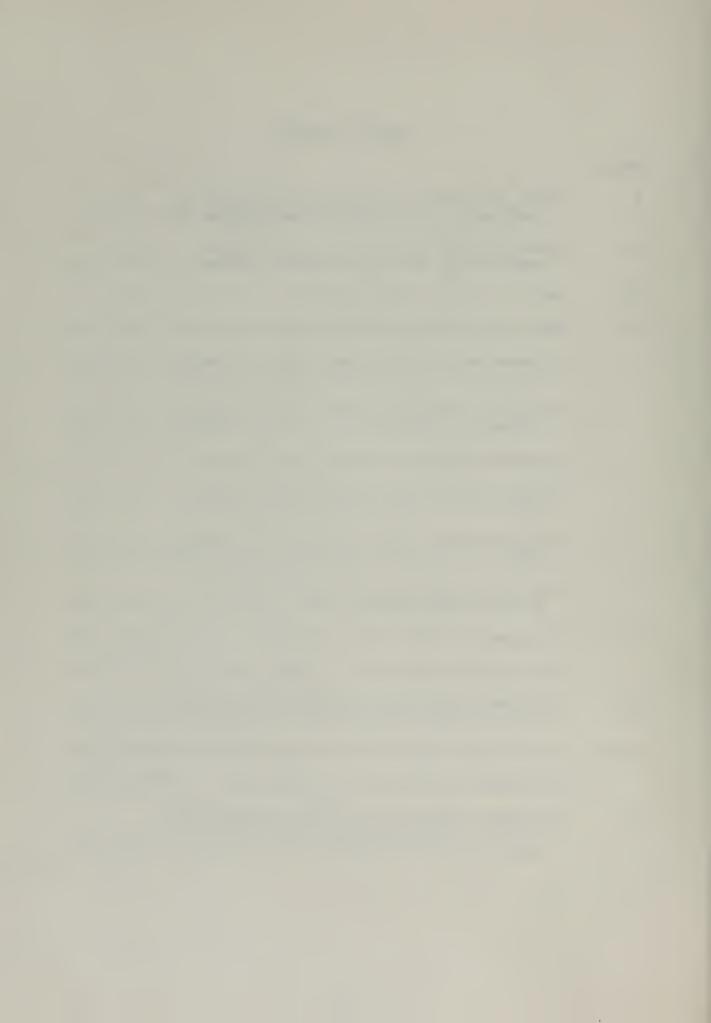
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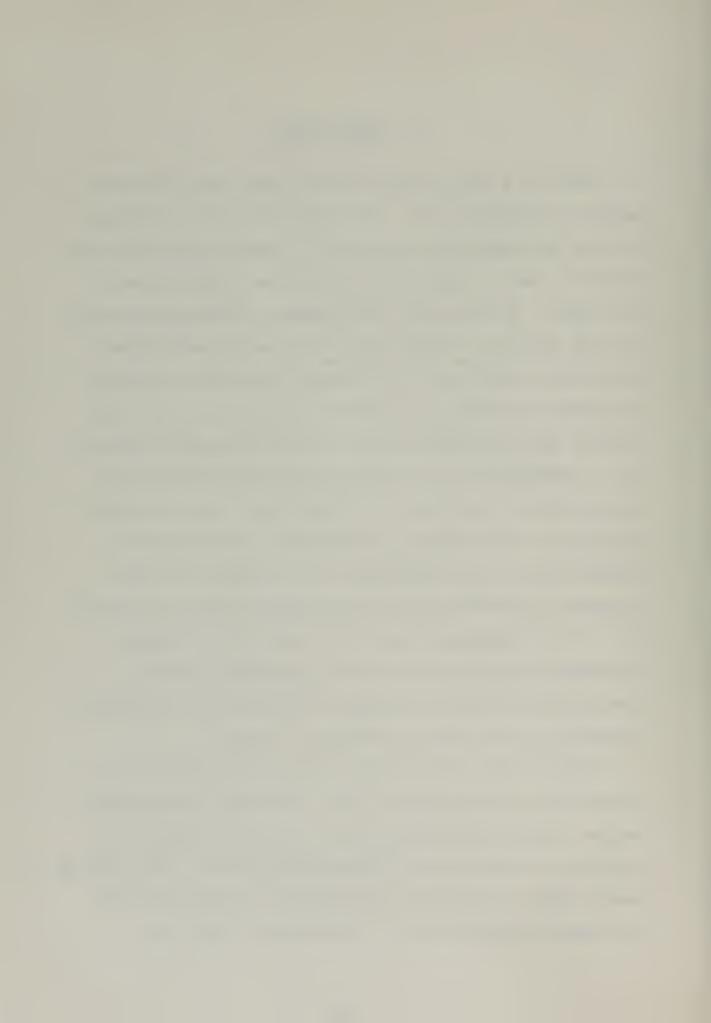
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I. INTRODUCTION

There is a basic oneness of the human and veterinary medical professions [1]. Many diagnostic and therapeutic devices developed for use in one of these professions have sooner or later found equally significant application in the other. In particular, the advent of automated devices for the analysis of human serum has greatly facilitated biochemical profiling [2]. However, as Coffman reports, restricted availability of these devices in the past has limited their practicality in clinical veterinary medicine [3]. Coffman goes on to point out, and this writer has encountered no statement to the contrary, that the applicability of these devices, in enhancing the diagnostic capabilities of the clinician, will be cause for their increased utilization by the veterinary medical profession [4]. It is therefore logical to assume that automated biochemical profiling will be of increasing value in describing the normal intervals about the true biochemical parameters in the serum of domestic animals.

Although the auto-analyzer devices are capable of generating a large volume of data concerning biochemical values in human and animal sera, the proper analysis of these data should not be treated superficially. The lack of proficiency in statistical methodology by members of the bio-medical professions is an unfortunate fact [5].



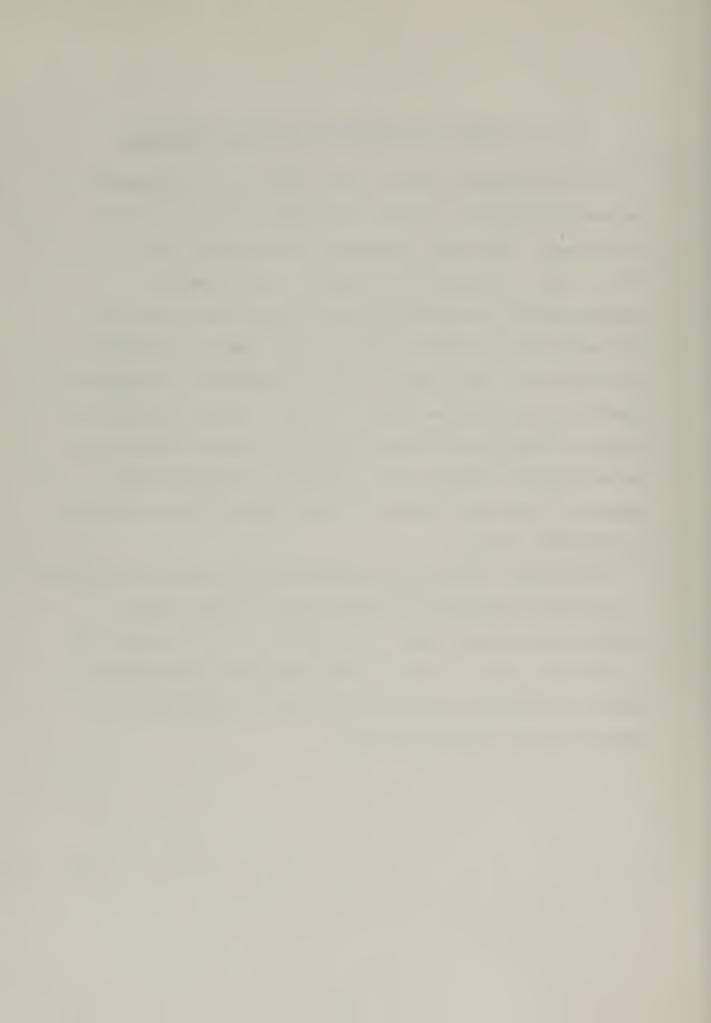
Additionally, qualified statisticians are often asked to make meaningful conclusions from biological data that have been generated in meaningless fashion [6]. The increased reliance of the veterinary medical profession upon automated analyzing devices will yield little addition to our knowledge of serum biochemical parameters and their concomitant physiological significance unless the data are meaningfully collected and analyzed by sophisticated statistical techniques. It is this conclusion which has motivated the research effort reported herein.



II. A BRIEF CONSIDERATION OF THE AUTOANALYZER

The autoanalyzer used in this study was a Technicon Sequential Multiple Analyzer, SMA 12/60, which was first introduced in 1967 as a successor to the widely used SMA 12 [7]. The SMA 12/60 analyzes a serum sample quantitatively and reports on the concentration of 12 of the serum biochemical components on an easily interpreted pre-calibrated chart paper. The 12 biochemical components quantitatively analyzed are: calcium, inorganic phosphate, glucose, blood urea nitrogen (BUN), uric acid, cholesterol, total protein, albumen, total bilirubin, alkaline phosphatase, lactic dehydrogenase (LDH), and glutamic oxalacetic transaminase (SGOT).

The primary value of the autoanalyzer is that it provides a reasonable biochemical profile of the subject from a single serum sample within 60 seconds; it is invaluable as a screening device in that certain metabolic aberrations, whether suspected or unsuspected, will be manifested in abnormal serum chemistry charts.



III. THE MAMMALIAN SPECIES UNDER STUDY AND COLLECTION OF SAMPLES

The horse has recently enjoyed a resurgence of popularity although it is more in demand as a pleasure and recreation animal rather than a source of agricultural power. It was selected for this study because it was felt that the economic value of the horse justifies the most sophisticated diagnostic techniques by consulted veterinarians. While some data are available as to equine biochemical parameters the work thus far reported does not fully exploit the statistical potential of these data [8].

In this study, 44 horses of various breeds, 23 males and 21 females, were selected. All were clinically in good health. Blood samples were obtained by vena puncture; the serum was separated from the clot and was then centrifuged, frozen, and maintained in a frozen state until submitted to the laboratory.

The cat was selected for this study because information concerning biochemical parameters in the serum of this animal is particularly lacking [9]. Thirty (30) cats, 15 males and 15 females, all of mixed breed but of varying ages were included in this study. All were free of clinical illness. Blood samples were obtained by cardiac puncture and the samples were then processed as described above.



IV. TABULAR PRESENTATION OF DATA

In consideration of the equine data 14 variables were under consideration; in addition to the 12 serum biochemical components reported by the autoanalyzer, body weight and age were also considered. A previous report indicates that equine serum albumen is not reliably reported by the autoanalyzer [10]. Albumen is nonetheless included in this study to form a basis for substantiation or repudiation of this fact as may be justified by further research.

A similar approach was employed with the feline data with the exception that 13 variables were under consideration; inasmuch as no cat demonstrated measurable total bilirubin it was deleted from consideration.

The data as reported by the SMA 12/60 Auto-analyzer for the 44 horses and 30 cats are presented in Table I and Table II respectively.

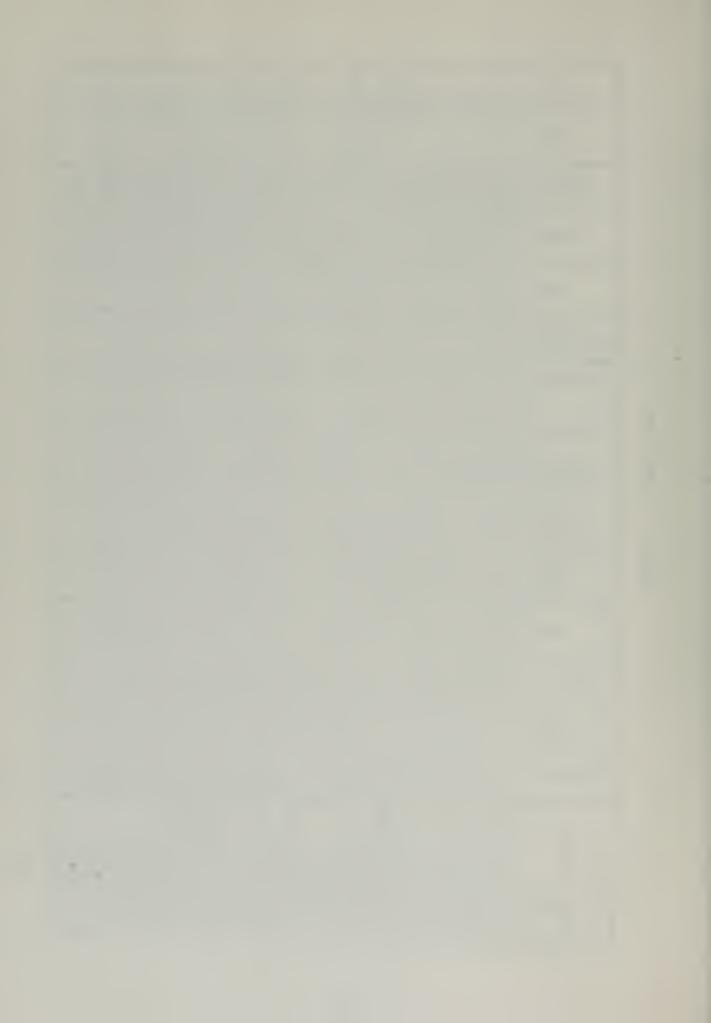


SERUM BIOCHEMICAL VALUES IN 44 HORSES AS REPORTED BY AN AUTO-ANALYZER SYSTEM

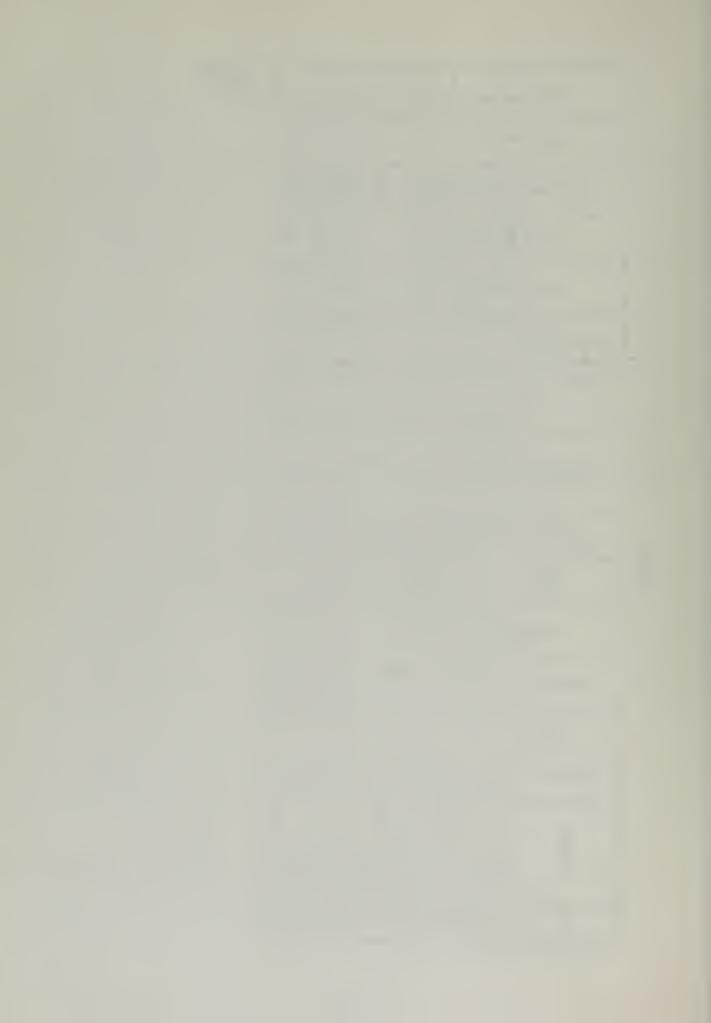
xəs	ᄕ	[편-	Σ	Ē	* \	ĹΉ	* \	× W	W*	M*	F-	F.	× W	F-	F	M*	
	<u>, H</u>	11	.5	.5 E	24	14		24	24	24	Ŀ	.5 F	2	F	표	24	ഥ
Age	13	8	0	0	2	14	6	4	3	5	14	1	7	8	5	4	10
Меідћ	850	1000	200	200	1075	1100	1050	950	1200	1100	1050	800	1100	1100	1200	1100	1.150
CCOT	460	560	650	740	260	1290	530	750	260	840	1330	700	630	630	630	590	590
грн	211	224	250	255	205	187	3.0	325	259	250	250	240	250	150	265	141	252
Phos.	87	105	490	350	111	118	78	125	172	120	138	335	95	121	107	146	92
.T niduriLia	6.0	1.0	0.7	0.8	1.3	2.0	1.2	1.0	1.0	0.8	9.0	6.0	1.0	0.8	1.2	0.8	1.1
А1Ъител	9.0	9.0	9.0	9.0	0.5	0.4	0.4	0.5	0.5	9.0	0.5	0.4	0.5	0.5	9.0	0.5	0.5
Total	6.4	6.9	5.7	5.5	6.5	6.8	9.9	6.3	9.9	6.5	6.3	9.9	5.8	6.3	0.9	6.4	6.5
Choles-	110	135	135	152	101	94	06	107	142	112	111	101	100	118	110	104	112
Uric	0.5	0.5	0.5	1.0	0.4	0.4	0.4	0.4	0.4	0.7	0.4	0.4	0.3	0.4	0.8	0.3	0.3
BUN	10	11	13	12	91	19	24	18	21	14	16	13	11	16	15	17	11
egncose	86	85	98	102	76	79	78	85	94	83	80	105	79	81	86	85	72
Inor.	3.3	3.1	6.4	6.7	4.0	3.1	3.3	3.4	3.7	3.7	3.7	5.1	3.2	3.7	3.8	2.7	3.7
Galcium	11.2	11.8	12.0	11.3	11.2	10.5	11.4	11.0	12.1	11.6	11.1	12.2	11.8	12.2	11.9	11.6	11.5
Breed	Grade	Grade	Qtr.Horse	Qtr.Horse	Qtr.Horse	Grade	Qtr.Paint	-	1	i	1	1	Palomino	Grade	Grade	Grade	Qtr.Horse
No.	7	2	3	4	2	9	7	8	6	10	11	12	13	14	15	16	17



xəg	균	ഥ	*W	W*	냰	W*	W*	ഥ	Ĺ	*W	ഥ	W*	W *	W*	댸	ᅜᅺ	*W	*W
уде	2	6 .	9	6	6	3	7	13	.9	4	9	12	.12	10	7.5	4	12	5
Меідћ	1000	1100	006	1000	1000	1200	1050	006	1000	1000	900	850	1000	1100	006	750	1000	1000
TODS	750	540	530	1080	1410	750	850	680	2500	600	410	480	490	800	640	640	630	2100
НGЛ	550	185	200	230	235	221	206	206	240	213	165	176	109	224	190	260	168	285
Alkaline Phos.	207	138	150	135	147	135	105	66	75	114	106	145	88	125	96	195	171	136
T. Ridurifia	1.1	1.7	0.8	0.5	0.8	6.1	2.3	1.8	1.2	1.2	1.0	1.8	2.8	2.1	1.0	1.2	1.6	1.3
Albumen	0.5	0.4	0.5	0.5	0.5	0.1	0.4	0.4	9.0	0.5	0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.5
Total Protein	6.1	6.5	6.5	6.2	6.1	6.5	6.5	6.4	0.9	6.4	7.0	9.9	7.0	7.1	6.3	6.7	6.4	6.5
Choles-	120	130	104	06	108	120	119	130	121	107	107	93	118	110	150	92	95	93
Uric	0.5	0.4	0.3	0.5	0.5	0.4	0.4	0.4	0.7	0.4	0.4	0.4	0.5	0.4	0.4	9.0	0.4	0.3
вли	14	15	16	11	12	ω	14	16	16	15	ω	12	19	13	16	17	15	18
Glucose	84	85	85	84	75	81	75	84	89	85	80	80	145	9.7	87	80	77	95
Inor.	5.2	4.1	3.2	3.5	3.3	4.4	3.5	3.7	2.3	4.4	2.9	2.9	2.2	2.9	3.7	4.1	3.9	3.5
muislad	11.3	11.4	13.1	12.8	12.7	10.5	12.1	11.5	11.8	11.9	12.2	11.8	11.0	12.3	11.4	11.4	11.2	12.1
Breed	Qtr.Horse	Grade	Appaloosa	Grade	Palomino	Appaloosa	Grade	Grade	Amer. Sadl.Bred	Arabian	Grade	Palomino	Qtr.Horse	Std.Bred	Grade	Grade	Grade	Throw- Quarter
No.	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35



F = 21 M = 23 44

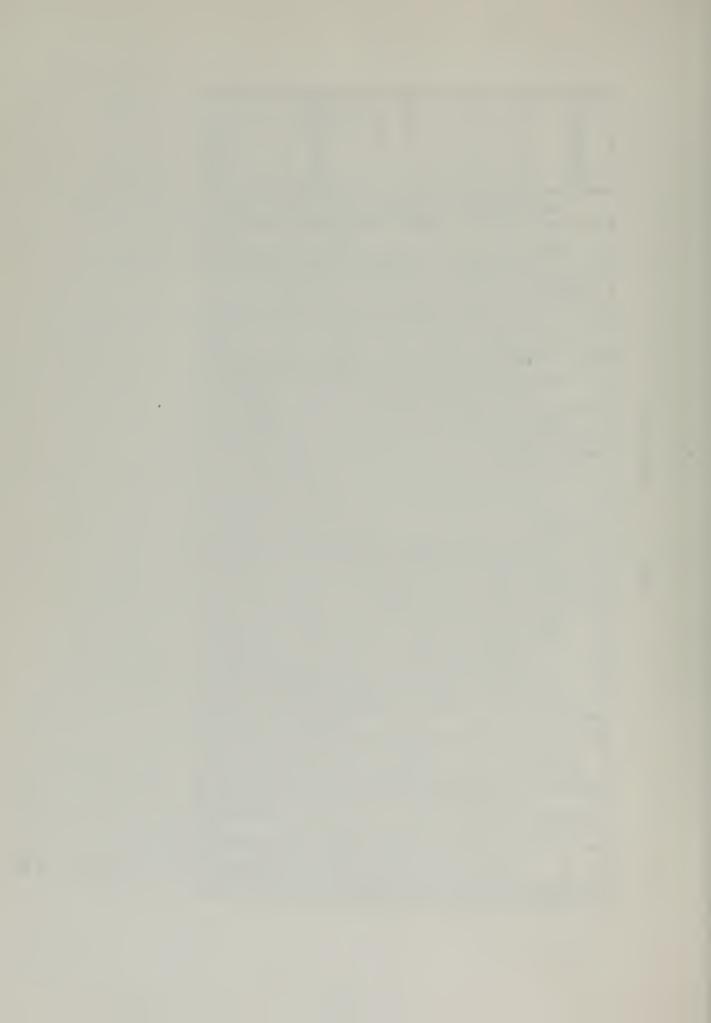


SERUM BIOCHEMICAL VALUES FOR 30 CATS AS REPORTED BY AN AUTO-ANALYZER SYSTEM

Comments															Spayed		
xəs	M	M	M	দ	M	균	균	M	দ	M	M	দ	M	돠	댼	M	Σ
yde	2	4	0.5	1	1.5	1	3	4	4	0.7	2	0.8	0.3	0.3	3	2	1.5
Weight	7	10	4	7	8	7	12	5	5	7	7	5	3	3	7	8	7
TODS	135	80	70	09	62	58	85	74	100	73	48	52	72	58	78	164	93
ндл	240	265	3 5	135	195	280	375	375	310	750	310	250	320	215	220	275	340
Alkaline.	72	45	87	9.7	62	52	30	75	97	82	09	70	140	145	41	43	82
nəmudlA	1.8	1.6	1.2	1.7	1.6	1.7	1.5	1.1	1.5	1.4	1.5	1.5	1.4	1.6	1.7	1.8	1.6
Total	6.4	6.7	5.5	6.5	6.4	9.9	7.7	6.9	7.1	6.3	6.3	6.5	6.2	6.4	7.1	7.4	9.9
Choles-	115	134	92	75	75	85	107	97	112	69	95	99	45	53	152	100	131
Uric Acid	1.2	9.0	0.7	9.0	0.8	0.8	6.0	6.0	1.0	0.8	1.0	1.2	1.2	1.0	6.0	0.7	0.7
ВОИ	24	23	26	15	26	22	23	25	. 27	23	26	27	28	26	41	21	21
Glucose	69	58	70	64	54	09	09	50	89	30	69	5.8	80	86	65	62	38
Thorg.	7.3	6.8	7.8	6.8	7.3	6.8	6.0	9.0	8.7	7.8	8.0	7.9	7.9	7.4	5.9	8.0	8.5
muislaS	10.4	8.6	9.5	10.0	10.1	6.6	9.2	11.0	9.6	10.1	10.2	9.4	9.6	9.7	9.1	9.6	9.3
0 N	1	2	3	4	S	9	7	8	6	10	11	12	13	14	15	16	17



Comments									Neutered				Spayed
xəs	ഥ	Σ	দ	দ	Z	M	M	দ	Σ	ſτι	দ	দ	댼
уде	1	2	2	2	5	9	2	9.0	9	5	∞	г	1.5
Метдрь	9	11	5	9	10	8	8	5	6	12	7	2	6
SGOT	103	177	72	103	72	9.0	70	152	29	63	72	83	105
LDH	185	335	368	216	260	251	132	299	176	77	75	290	267
Alkaline Phos.	20	09	30	26	32	31	30	62	52	57	52	26	29
иЭшифТА	1.3	1.8	1.4	1.4	1.7	1.5	1.3	1.6	1.6	1.8	1.6	1.3	1.4
Total Protein	7.1	6.5	6.2	7.7	7.0	7.0	7.0	7.0	8.9	7.3	7.8	6.3	7.0
choles-	115	146	38	26	15	100	63	69	55	51	31	30	62
Uric	0.8	8 • 0	6.0	1.1	1.0	1.0	1.0	6.0	8.0	6.0	1.0	6.0	1.0
BUN.	20	27	26	34	32	29	31	26	21	26	22	18	29
clucose	55	112	69	55	70	9.0	80	110	166	117	16	9.2	97
Inorg.	7.8	8.2	5.3	6.1	6.4	7.4	4.7	9.2	5.7	5.8	9.9	8.4	7.4
Calcium	9.0	9.6	8.7	8.5	8.3	8.3	7.9	10.0	8.2	8.1	8.0	8.3	8.7
No.	18	19	20	21	22	23	24	25	26	27	28	29	30



V. SAMPLE STATISTICS

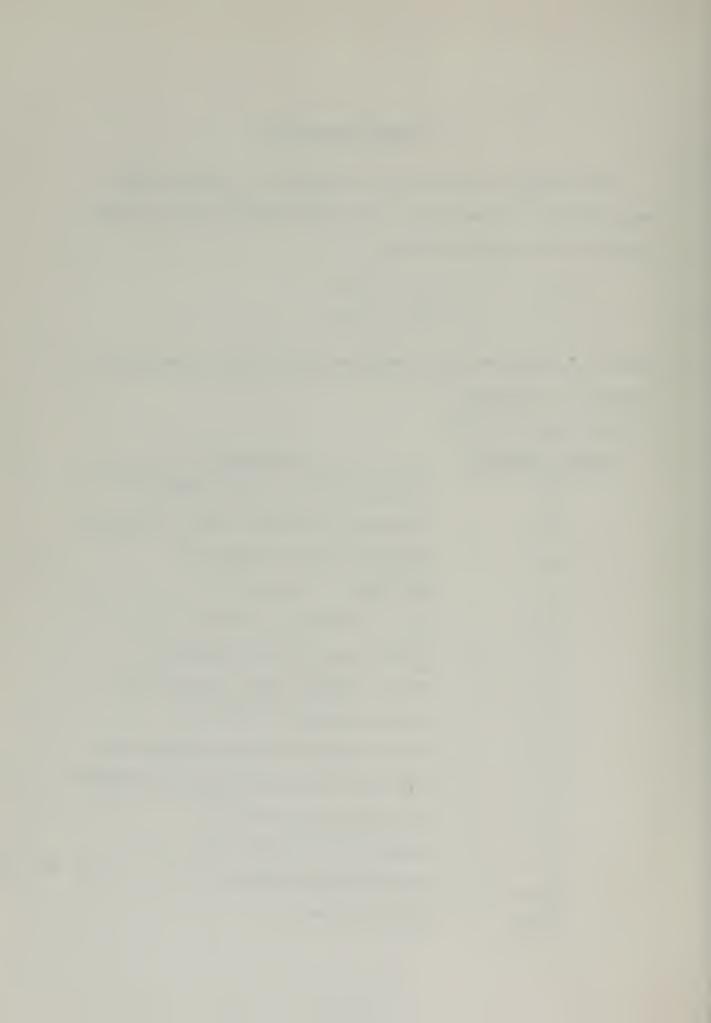
The analysis of the data is amenable to multivariate methodology. In the case of the equine data we have observations on 14 random variables:

$$x_{i,j}$$
 $i = 1,2,...,44$
 $j = 1,2,...,14$

where "i" refers to the identification of the animal and j refers to a variable.

In particular we have:

Random Variable	Definition
x _{i,1}	Calcium Level of Horse Number "i"
x _{i,2}	Inorganic Phosphate Level of Horse "i"
^X i,3	Glucose Level of Horse "i"
X _{i,4}	BUN Level of Horse "i"
X _{i,5}	Uric Acid Level of Horse "i"
X _{1,6}	Cholesterol Level of Horse "i"
X _{i,7}	Total Protein Level of Horse "i"
X _{i,8}	Albumen Level in Horse "i"
X _{i,9}	Total Bilirubin Level of Horse "i"
- X _{i,10}	Alkaline Phosphatase Level of Horse "i"
X _{i,11}	LDH Level of Horse "i"
X _{i,12}	SGOT Level of Horse "i"
X _{i,13}	Body Weight of Horse "i"
^X 1,14	Age of Horse "i"



In the case of the cat we have observations on 13 random variables:

$$Y_{i,j}$$
 $i = 1,2,...,30$
 $j = 1,2,...,13$

where "i" and "j" again refer to the identification of the animal and the characteristic respectively.

In particular we have:

Random Variable	Definition
Y _{i,1}	Calcium Level of Cat "i"
Y _{i,2}	Inorganic Phosphate Level of Cat "i"
Y _{i,3}	Glucose Level of Cat "i"
Y _{i,4}	BUN Level of Cat "i"
Y _{i,5}	Uric Acid Level of Cat "i"
^Y i,6	Cholesterol Level of Cat "i"
Y _{i,7}	Total Protein Level of Cat "i"
Y _{i,8}	Albumen Level of Cat "i"
Y _{i,9}	Alkaline Phosphatase Level of Cat "i"
Y _{i,10}	LDH Level of Cat "i"
Y _{i,11}	SGOT Level of Cat "i"
Y _{i,12}	Body Weight of Cat "i"
^Y i,13	Age of Cat "i"

In the description of sample statistics that follow, the computational formulae are given for $x_{i,j}$. The same formulae apply for $y_{i,j}$ and it is understood that N=44 and N=30 for the horse and cat respectively.



In multivariate terminology, each horse may be represented as a 14 dimensional vector $\underline{\mathbf{x}}^{(i)}$. For example, referring to Table I we see that horse number 1 is represented as follows:

$$\begin{bmatrix}
x_{1,1} \\
x_{1,2} \\
3_{1,3} \\
x_{1,4} \\
x_{1,5} \\
x_{1,6} \\
x_{1,6} \\
x_{1,7} \\
x_{1,8} \\
x_{1,9} \\
x_{1,10} \\
x_{1,11} \\
x_{1,12} \\
x_{1,13} \\
x_{1,14}
\end{bmatrix}$$

$$\begin{bmatrix}
11.2 \\
3.3 \\
86. \\
10. \\
0.5 \\
110. \\
6.4 \\
0.6 \\
0.9 \\
87. \\
211. \\
460. \\
850. \\
13.
\end{bmatrix}$$

The sample mean, \bar{x} , is required for each of the set of observations on the 14 variables and is computed as follows:

$$\bar{x}_{\cdot,j} = \sum_{i=1}^{N} \frac{x_{i,j}}{N}$$

The sample means of the observations on the j variables may be represented as a j-dimensional sample mean vector, $\bar{\mathbf{x}}$, where



$$\bar{x} = \begin{bmatrix} \bar{x} \\ \bar{x} \\ \bar{x} \\ 2 \end{bmatrix} = \frac{1}{N} \begin{bmatrix} \sum_{i=1}^{N} x_{i,1} \\ \sum_{i=1}^{N} x_{i,2} \\ \vdots \\ \sum_{i=1}^{N} x_{i,2} \\ \vdots \\ \sum_{i=1}^{N} x_{i,j} \\ \vdots \\ \sum_{i=1}^{N} x_{i,j} \\ \vdots \\ \sum_{i=1}^{N} x_{i,j} \end{bmatrix}$$

The 6 sample mean vectors representing 44 horses, 23 male horses, 21 female horses, 30 cats, 15 male cats, 15 female cats, are presented in Table III.

The sample variance, s_j^2 or $s_{j,j}$ is computed for each set of observations on the j variables as follows:

$$s_{j}^{2} = \frac{1}{N-1} \sum_{i=1}^{N} (x_{i,j} - \bar{x}_{i,j})^{2}$$

The sample standard deviation is computed by simply obtaining the square root of the sample variance:

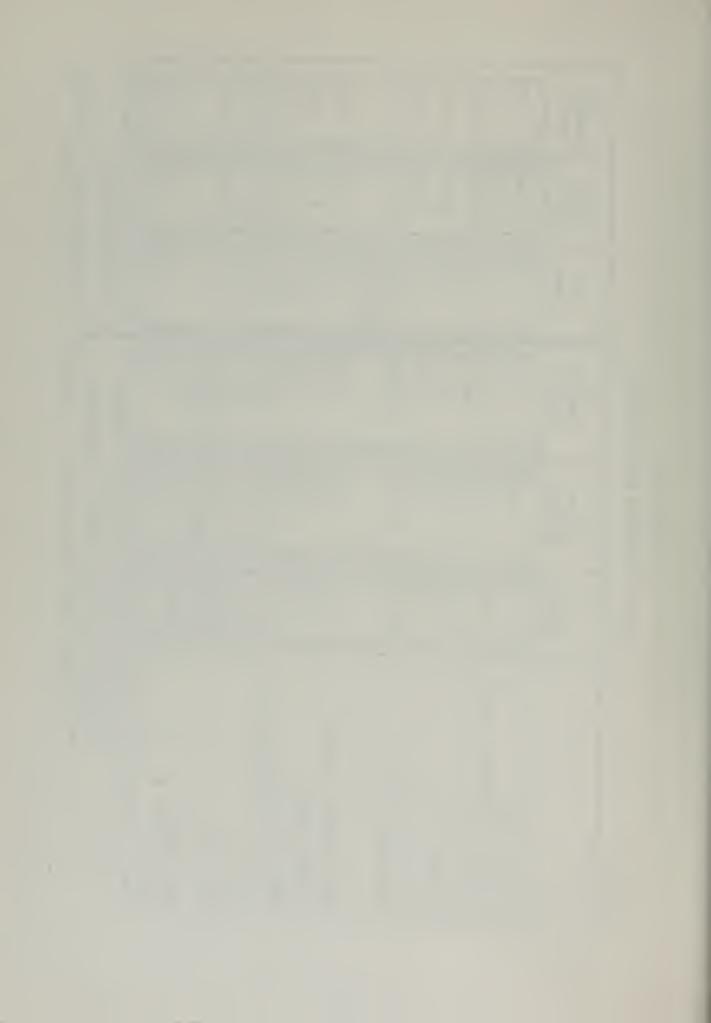
$$s_j = \sqrt{s_j^2}$$

The sample covariance, $s_{j,k}$, between the observations $x_{i,j}$ and $x_{i,k}$, $i=1,\ldots,N$, is computed as follows:



TABLE OF SAMPLE MEAN VECTORS

-	44 Horses	23 Male Horses	21 Female Horses	30 .Cats	15 Male Cats	15 Female Cats
CALCIUM (mg%)	11.78	11.87	11.70	9.27	9.46	9.08
INORGANIC PHOSPHATE (mg%)	3.62	3.49	3.75	7.23	7.39	7.07
GLUCOSE (mg%)	86.77	88.57	84.81	75.53	73.20	77.87
BUN (mg%)	14.55	14.78	14.29	25.50	25.53	25.46
URIC ACID (mg%)	0.45	0.43	0.48	06.0	0.88	0.93
CHOLESTEROL (mg%)	112.70	108.52	117.29	•	87.73	71.47
				**97.33		
TOTAL PROTEIN (gms%)	5.49	6.55	6.43	6.78	09*9	6.95
ALBUMEN (gms%)	0.48	0.47	0.50	1.53	1.53	1.53
TOTAL BILIRUBIN	1.40	1.56	1.22	N/A	N/A	N/A
ALKALINE PHOSPHATASE T.U.	145.39	144.52	146.33	60.67	63.53	57.80
LDH T.U.	223.57	217.74	229.95	271.03	302.60	239.47
SGOT T.U.	786.36	714.35	865.24 ***615.00	86.37	89.60	82.93
BODY WEIGHT	986.93	1022.83	947.62	7.10	7.47	6.73
AGE	L 7.14	6.89	7.40	2.26	2.43	2.08
*6 animals **1 male wi ***5 female	with SGOT > 1200 T ith SGOT > 1200 T.U es with SGOT > 1200		U. deleted deleted T.U. deleted	*6 animals < 50 mg% d **9 animals < 60 mg%	s with delete is with	cholesterol d cholesterol ed



$$s_{j,k} = \frac{1}{N-1} \sum_{i=1}^{N} (x_{i,j} - \bar{x}_{i,j}) (x_{i,k} - \bar{x}_{i,k})$$

In multivariate analysis the sample variances of the observation on the variables and the sample covariances between each pair of these variables is presented as a sample variance-covariance matrix (S) with dimensions p by p. The elements of the sample variance-covariance matrix are as follows:

$$(s) = \begin{bmatrix} s_{1,1} & s_{1,2} & s_{1,3} & \cdots & s_{1,k} & \cdots & s_{1,p} \\ s_{2,1} & s_{2,2} & s_{2,3} & \cdots & s_{2,k} & \cdots & s_{2,p} \\ \vdots & & & & & & \\ s_{j,1} & s_{j,2} & s_{j,3} & \cdots & s_{j,k} & \cdots & s_{j,p} \\ \vdots & & & & & \\ s_{p,1} & s_{p,2} & s_{p,3} & \cdots & s_{p,k} & \cdots & s_{p,p} \end{bmatrix}$$

In the main diagonal of the matrix j is equal to k and the main diagonal elements represent the sample variances for each of the j variables. Since $s_{j,k} = s_{k,j}$, for the sample variance-covariance matrices computed, those elements above the main diagonal will be deleted and the matrices will be lower triangular. The variance-covariance matrices for 44 horses, 23 male horses, 21 female horses, 30 cats, 15 male cats, and 15 female cats are presented in Tables IV, A thru F.

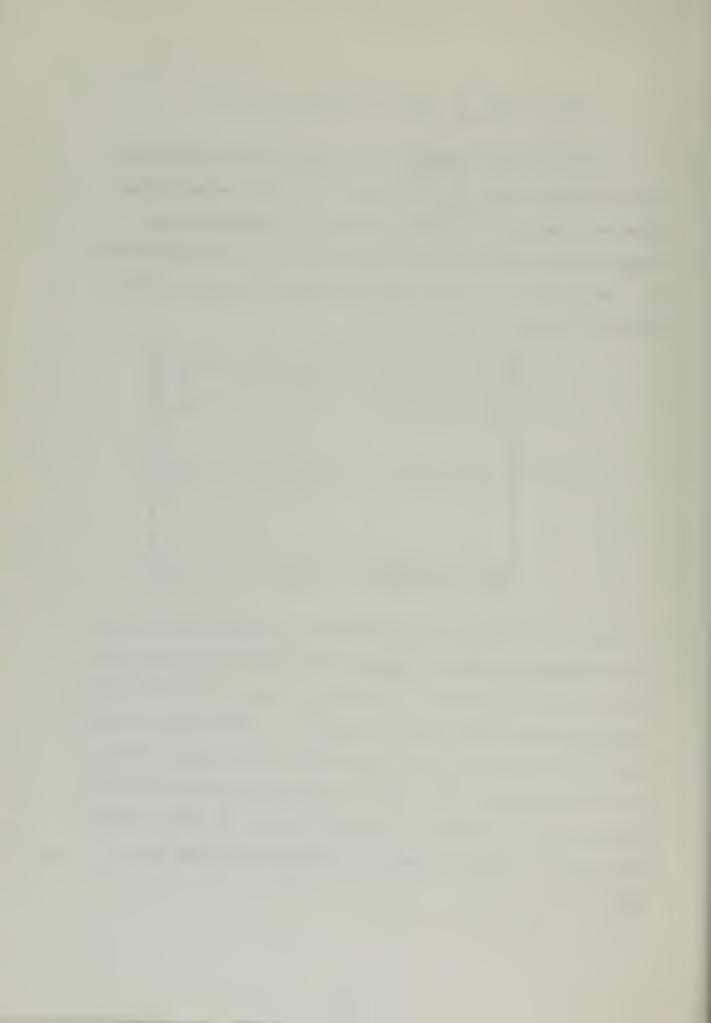


TABLE IV-A

VARIANCE-COVARIANCE MATRIX FOR 44 HORSES

888 yde 26874. 161. 12⁴ метдрг Bogk 562 -21.936188153 CCOL 3887 3396. -611. 835 012 4557. -87. IDH -8091. -2036. 5988. 516 134 921 1189. ·soyd -153. Alka. ←111. 819 526 0.204 861 0.807 Bilirubin 14. Total 090 0.976 -4. 545 0.008 0.854 -0-Albumen 955 -9. -0.0 -10. 681 0.430 0.162 0.129 Protein Total 343. .437 -765. 981 623 191 0.183 72.846 -1.300-501. terol 234 суотьз-0 340 -0. -0. 5.459 120 0.006 0.021 3.025 Acid Uric 533 -0.0 6.288 -32. 285 0.250 -0. -0. 122 -0. 635 180. 13,835 BUN 209320 -709. -473. 317 313 388 542 542 331 38.768 041 0.488 -143. 55 egncose 0-0 0 9 1290-1 1-0-184 -45. -84. 344 875 102 934 4.647 0.012 0.162 0.050 · soyd 0.84 .paonI 54 0-25 -0. -0. 134 -0. -0. 11. -0. 1.599 670 608 0.003 0.044 0.020 0.37 Calcium Phosphatase Cholesterol Inorganic Phosphate Bilirubin Alkaline Calcium Glucose Protein Albumen Weight Total Total Uric Body SGOT Age BUN LDH

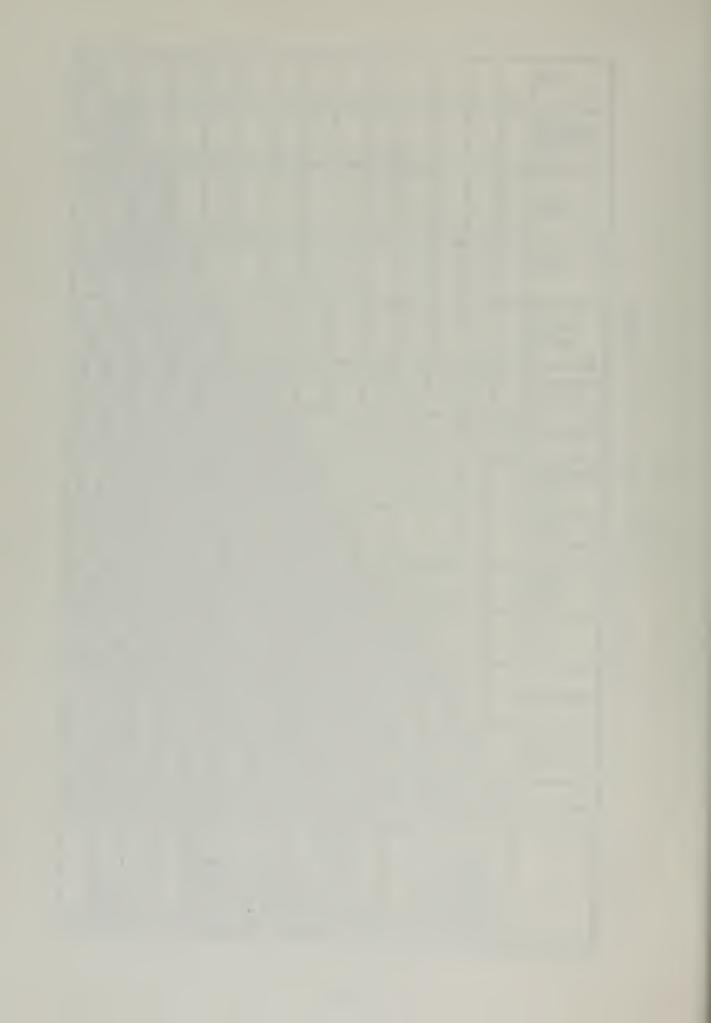


TABLE IV-B
VARIANCE-COVARIANCE MATRIX FOR 23 MALE HORSES

										- 1				
уде														9.817
воду Воду													25733. 664	48.
TODS			·									111907.	2566. 693	-179. 960
грн											2866. 743	6547. 984	-867. 636	-70. 348
Phos.										6708. 227	0.9	-359 . 644	-8465. 828	-117. 032
Total Bilirubin									1.284	-15. 492	-11. 520	-15 , 276	43.	0.193
пэшиdlА								0.012	100	2.164	0.868	1.476	-6.	-0.
Total Protein							0.131	-0.	0.106	-12. 615	-5. 600	-13. 782	25.	0.570
Choles-						199. 624	0.440	-0.	3.262	605. 258	73.870	-1062. 370	-95. 404	-20. 918
Uric Acid					0.014	0.502	1070.009	0.004	0.003	1.506	0.663	-6. 411	-5. 726	0.042
BOM				15. 632	-0. 138	-7. 063	0.107	0.092	-1.	-69. 791	26.	48. 716	69.	
erncose			227. 983	7.583	0.237	52. 419	1.642	-0.	1.932	49.	-317. 527	ļ I	-308. 941	9.246
Inorg.		0.718	-3.	-0.	0.023	4.078	-0.	0.0	0.024	49.	16.	16.	-78.	-1.
Calcium	0.432	-0. 910	-0. 466	-0.	0.014	-0. 472	0.028	0.036	-0. 352	4.196	0.186	22.	-27.	0.253
	Calcium	Inorganic Phosphate	Glucose	BUN	Uric Acid	Cholesterol	Total Protein	Albumen	Total Bilirubin	Alkaline Phosphatase	ГДН	SGOT	Body Weight	Age

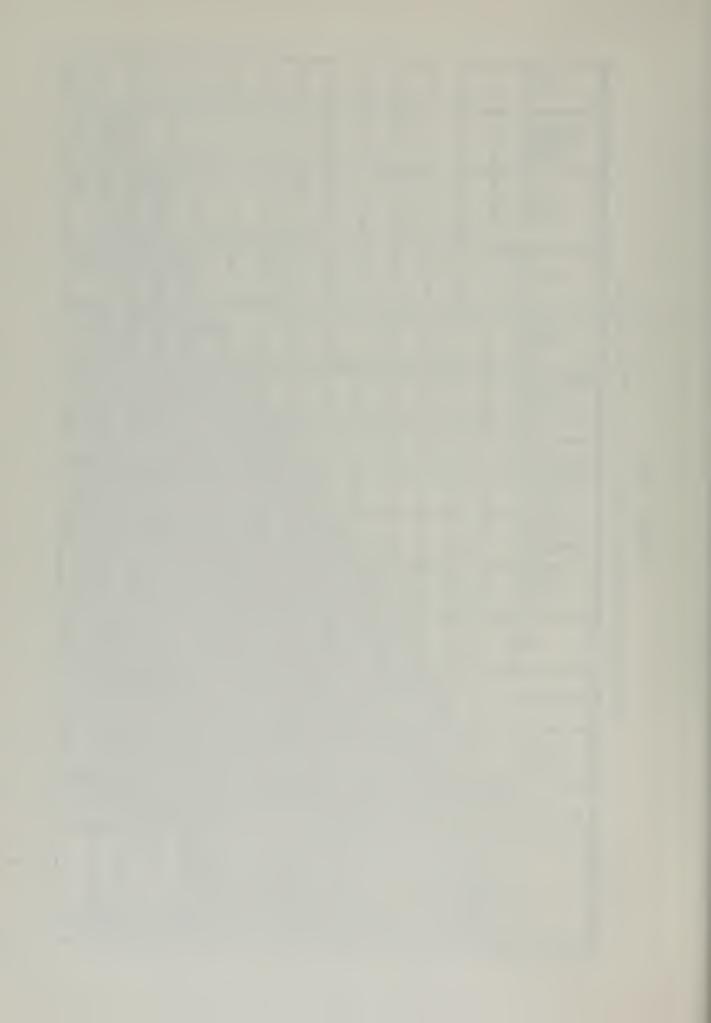


TABLE IV-C

VARIANCE-COVARIANCE MATRIX FOR 21 FEMALE HORSES

yde														16. 765
Body													26369.	314.
TODS												268935. 688	11763.	108.273
грн											6562. 324	6-	144. 87	-114. 905
Phos.										5495. 410	1773. 714	-4133. 809	-8009. 137	-201. 016
TetoT nidmilia									0.261	-8°-	-9. 849	76		0.322
Albumen								0.005	-0.	-0. 580	0.910	4.900	-0· 750	-0.
Total Protein							0.195	-0-	0.138	-8. 965	-12.964	6.143	17. 072	0.333
Choles-						242. 014	-2. 684	0.280	-1.	64. 599	16. 614	-1204. 070	-611. 784	-7. 821
Uric Acid					0.029	0.746	-0. 040	0	-0. 019	4.797	3.469	14.	-9. 548	-0. 319
вои				12. 414	-0. 074	-6. 036	-0. 414	-0. 105	0	7.850	-11. 986	37	-29. 286	0
esoonto			75. 562	4.207	0.556	43.	-1. 994	0.035	-1.	399.	65. 840	-976. 450	-832. 974	-18. 394
Inorg.		0.994	4.466	-0. 021	0.076	4.249	-0. 174	0.002	-0.	62. 936	34.	-138. 788		-2.
Calcium	0.320	-0-	-0.	-0-	-0. 004	-0. 494	0.053	900.0	900	-1. 008	'	13.	9.238	808
	Calcium	Inorganic Phosphate		BUN	Uric Acid	Cholesterol	Total Protein	Albumen	Total Bilirubin	Alkaline Phosphatase	грн	SGOT	Body Weight	Age .

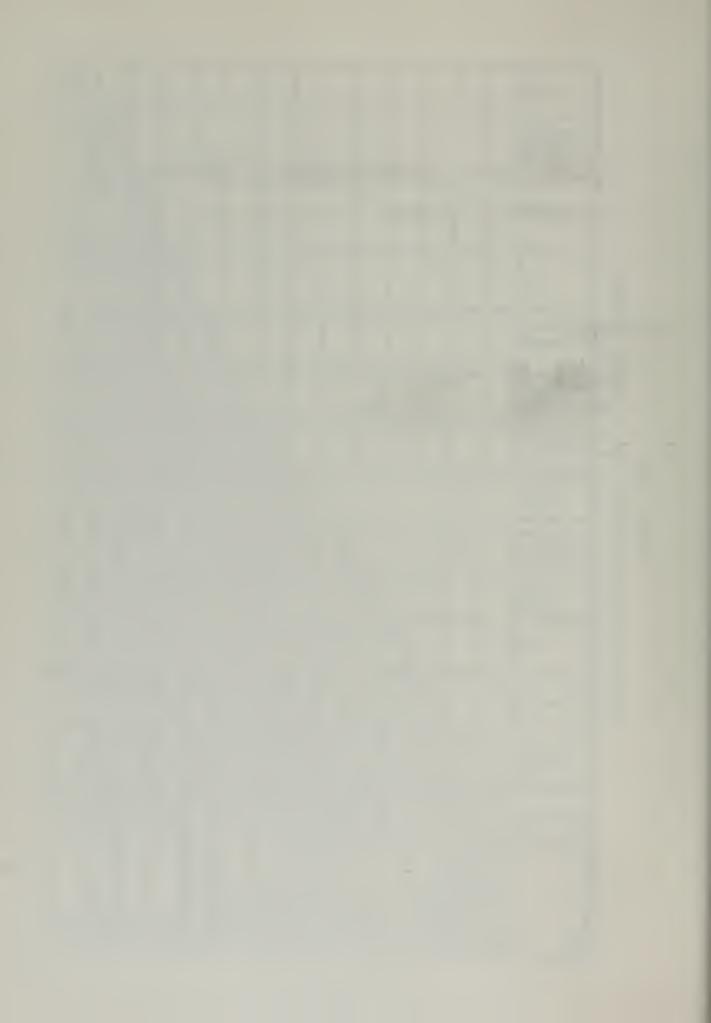


TABLE IV-D VARIANCE-COVARIANCE MATRIX FOR 30 CATS

yde													3.789
Body Weight												5.610	2.587 3
TOSS			·								1046.	2.859	6.246
грн								J		88 88		-42. 383	-99.
Alka. Phos.									952. 366	656. 837	-193. 217	-40. 517	-26. 691
иэшиdlА								0.034	0.069	-6.		0.211	0.
Total Protein							0.265	0.019	-8° 098	-21. 410	3.957	0.533	0.516
Choles-						1342. 660	-0.	1.550	-44. 241	7 <u>18</u> . 806	443.	19. 628	-9. 518
Uric Acid					0.026	-2. 085	0.011	-0. 004		-1.862	-0-	104	
вии				25.	0.388	2.793	0.460	-0.		-30. 431	-0.		0.867
egncose			747.843	-1.	0.488	-269. 951	1.327	1.166	-8. 126	-1460. 532	113.	12.	23. 093
Inorg.		1.275	-5.	- 1	-0.	11.	-0.	-0.	15.	54. 192	13.	-1.	-1.
Muisled	0.659	0.543	-10.			13.		0.003	12.	44.	3.215	-0-	-0. 952
	Calcium	Inorganic Phosphate	Glucose	BUN	Uric Acid	Cholesterol	Total Protein	Albumen	Alkaline Phosphatase	ГДН	SGOT	Body Weight	Age

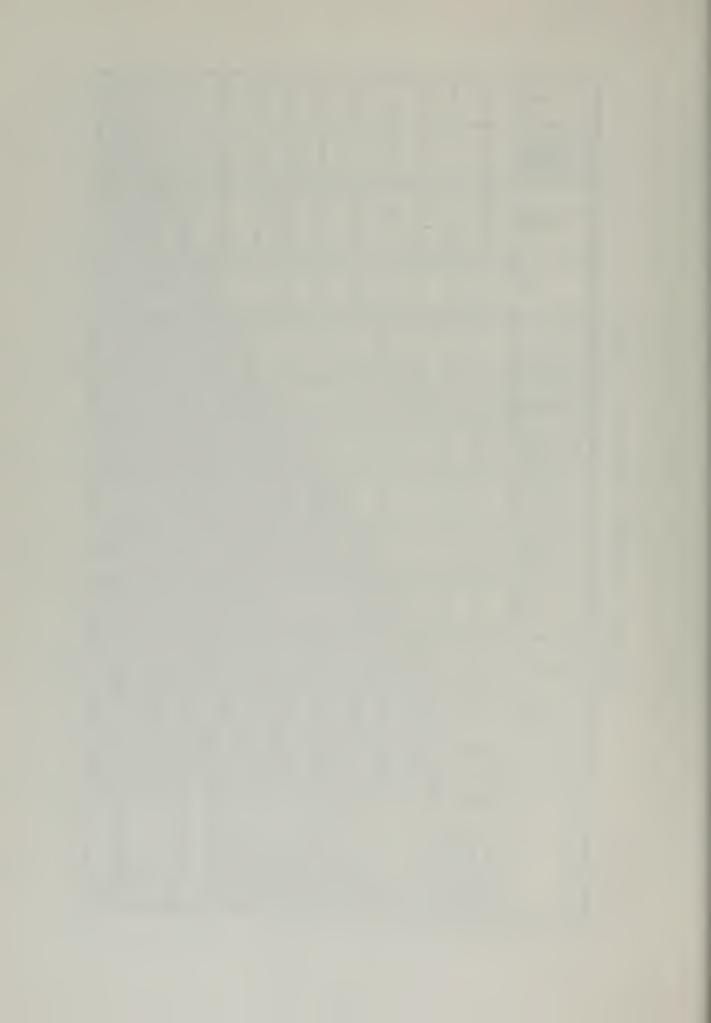


TABLE IV-E
VARIANCE-COVARIANCE MATRIX FOR 15 MALE CATS

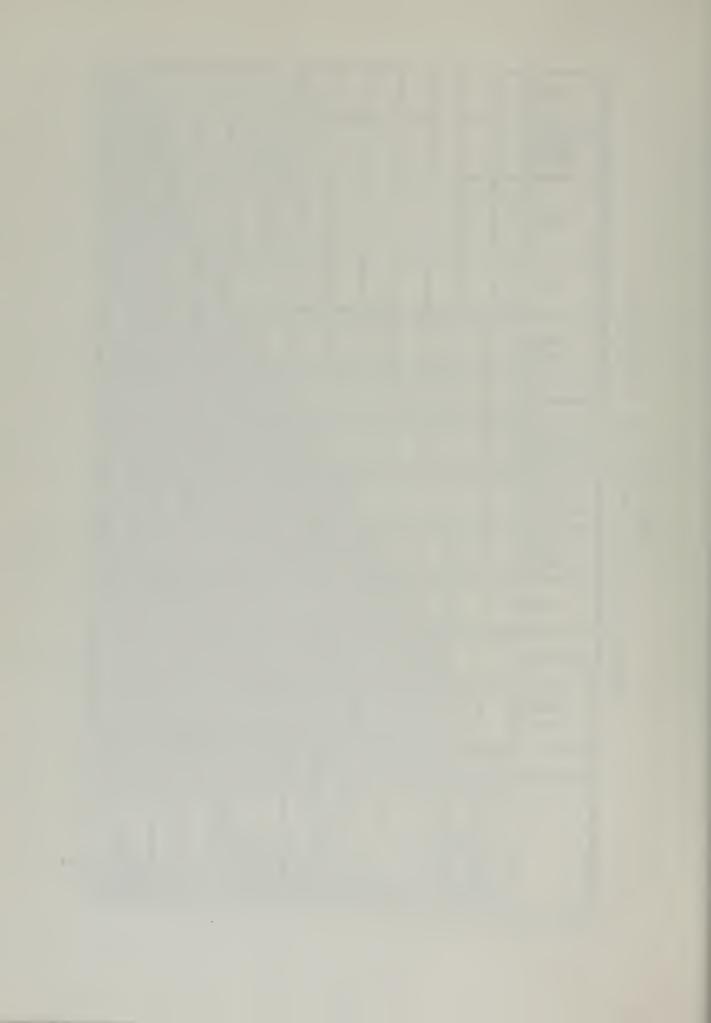
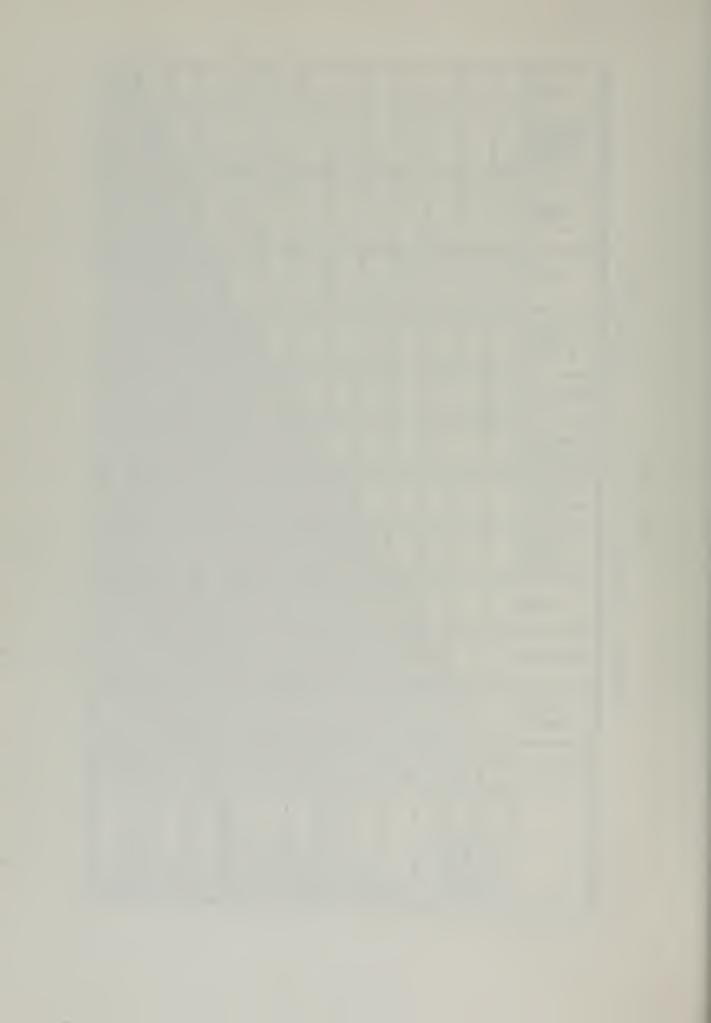


TABLE IV-F
VARIANCE-COVARIANCE MATRIX FOR 15 FEMALE CATS

yde													175
												16	4 4.
Body												6.495	2.59
LOSS											696.065	-5.305	-10.416
ГОН										8747.		-43. 081	-104. 211
Phos.									1141.	-430. 828	-288. 942	-37. 986	-19. 440
иэшис1А								0.024	2.071	- 6. 488	-1. 455	0.124	001.0
Total Protein							0.276	0.007	-7. 253	-13.	4.611	0.730	0.684
Choles- terol						1350. 835	2,388	1.119	-72. 114	697. 765	98.	15. 490	14.
Uric					0.019	-1.	0.016	900	-0-	1.794	0.173	-0.	0.028
ВПИ				39. 838	0.458	63.	0.938	0.112	-43. 828	62. 481	29.	-0. 081	966 • 0
esocnto			471.	-10. 505	0.182	-345. 004	0.072	0.883	185. 328	-621. 218	111.	6.319	13. 133
Inorg.		1.355	5.489	-1.	0.019	2.513	-0. 139	-0.	13	21. 556	14	-1. 458	-1. 195
muisleD	0.465	0.316	-4. 317		-0.		-0. 136	0.029	11.	21.	1.392	-9.7	-0. 944
	Calcium	Inorganic Phosphate	Glucose	BUN	Uric Acid	Cholesterol.	Total Protein	Albumen	Alkaline Phosphatase		SGOT	Body Weight	Age



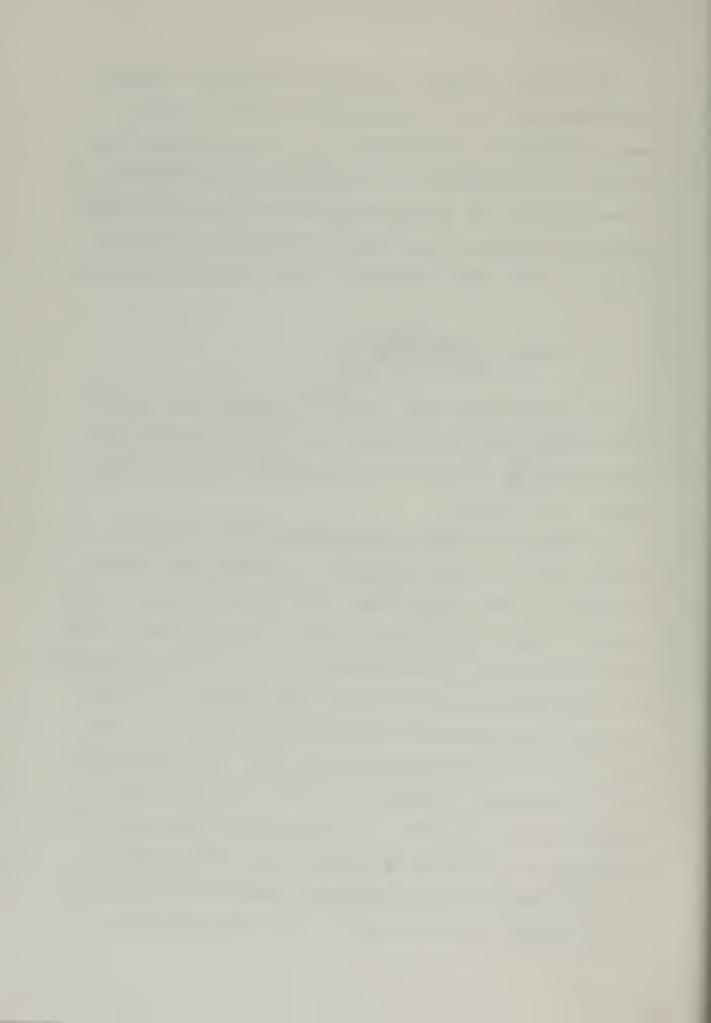
The primary purpose of computing the sample variance-covariance matrix is in computing the Pearson Product Moment Correlation Coefficient, $r_{j,k}$. This statistic is a measure of the tendency of 2 variables to vary together in linear fashion. It is described as the ratio of the sample covariance between 2 variables to the square root of the product of the sample variances of the 2 variables; that is,

$$r_{j,k} = \frac{s_{j,k}}{\sqrt{(s_{j,j})(s_{k,k})}}$$

For the equine data there are $\binom{14}{2}$ = 91 pair-wise correlation coefficients to be computed and for the feline data there are $\binom{13}{2}$ = 78 pair-wise correlation coefficients to compute and consider.

The tests of hypotheses conducted in this research effort rely on certain assumptions concerning the sample statistics. The central limit theorem, which permits us to assume a normal $(\mu, \frac{\sigma^2}{N})$ distribution of sample means in the univariate case [11], also permits us to make the assumption of normality in the multivariate case; namely, the distribution of the sample mean vectors, $\overline{\mathbf{x}}$, is normal with mean $\underline{\mu}$ and variance-covariance matrix $\frac{1}{N}$ Σ [12]. This assumption will be employed in testing the notion that the vector of sample means of the males of a given species does not differ significantly from that of females of the same species.

Additionally, if the population correlation coefficient, $\rho_{\text{j,k}}, \text{ between 2 variables equals zero, then the sample}$



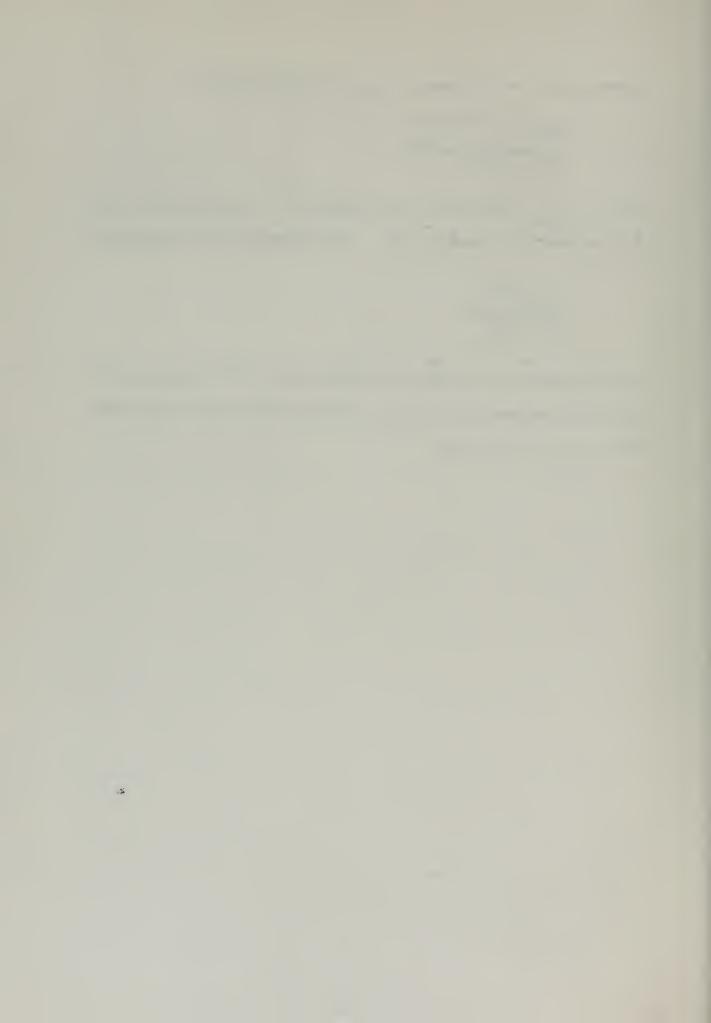
correlation coefficient, rj,k is distributed as

$$\frac{t_{(N-2)}\sqrt{(1-r_{j,k}^2)}}{\sqrt{N-2}}$$

where $t_{(N-2)}$ represents the Student "t" distribution with N-2 degrees of freedom [13]. Equivalently, the statistic

$$\frac{r_{j,k}\sqrt{N-2}}{\sqrt{1-r_{j,k}^2}}$$

is distributed according to the Student "t" distribution with N-2 degrees of freedom, provided that the hypothesis that $\rho_{j,k}$ = 0 is true.



VI. HYPOTHESES TESTED

A "null" hypothesis, denoted as $H_{\rm O}$, can be defined as a statement or notion for which it is possible to compute a statistic and the corresponding probability of a more extreme value of that statistic. Alternatively, it is common to establish a probability corresponding to the risk of rejecting $H_{\rm O}$ when, in fact, it is true and denoting this probability as α . $H_{\rm O}$ is then rejected only when the test statistic is more extreme than that associated with α .

In this study the following null hypotheses were tested:

1. H_0 : The true correlation coefficient $(\rho_{j,k})$ between variables j and k is equal to zero. This hypothesis was tested for both equine and feline data irrespective of the sex of the animal.

Since the sample correlation coefficient can be converted into a "t $_{(N-2)}$ " statistic, providing H $_{0}$ is true, it is possible to solve for the "critical" value of r $_{j,k}$ by establishing a type I error (α) and locating the appropriate "t $_{(N-2)}$ " value from a statistical table. In fact, this critical value of r $_{j,k}$, denoted r $_{\alpha j,k}$, is obtained as follows:

$$r_{\alpha j,k} = \frac{t_{\alpha}}{\sqrt{t_{\alpha}^2 + (N-2)}}$$

where t_{α} is the $1-\alpha$ percentile point of the "t" distribution with N-2 degrees of freedom. Conveniently, values of



 $r_{\alpha j,k}$ are already tabulated [14]. Those appropriate to the testing of this null hypothesis are presented in Table V.

TABLE V

CRI	TTICAL VALUES	OF rj,k FOR	SPECIFIED α
	N	$\alpha = 0.05$	$\alpha = 0.01$
44	(Horses)	0.298	0.385
30	(Cats)	0.367	0.470

Triangular matrices of sample correlation coefficients for the 44 horses and 30 cats are presented in Tables VI-A and VI-B respectively. In these tables those values of $r_{j,k}$ for which H_{o} : $\rho_{j,k} = 0$ can be rejected at $\alpha = 0.05$ are indicated by a* and those for which the hypothesis can be rejected at $\alpha = 0.01$ are indicated with **.



TABLE VI-A
CORRELATION MATRIX - 44 HORSES

Meight Body														0.274	0.385)
Tobs													0.055	-0.014	- ×, i
грн												0.116	-0.055	-0.362)1 (rj,k
Alka. Phos.											0.228	-0.061	-0.638	-0.551	$\alpha = 6.01$
TstoT nidvrili8										-0.170	-0.190	0.038	0.248	0.063	ه ٦
мЭшифТА									-0.727	0.120	0.157	0.109	-0.301	-0.129	significant
Total Protein								-0.242	0.358	-0.343	-0.342	-0.051	0.355	0.298	- sig
Choles-							-0.211	0.130	0.032	0.290	0.070	-0.115	-0.200	-0-) ; **
oirU bioA						0.322	-0.264	0.457	-0.089	0.269	0.215	0.087	-0.350	-0.231	0.298)
вли					-0.207	-0.132	-0.081	-0.018	-0.190	-0.112	0.025	0.112	0.052	0.019	.j,k ≥
esoonto				0.136	0.183	0.203	0.011	-0.036	0.044	0.217	-0.171	-0.131	-0.232	-0-	0.05 (r
Inorg.			0.014		0.376	0.330	-0.499	0.140	-0.081	0.770	0.404	-0.115	-0.561	0-	$\alpha = 0$
Calcium		-0.113	-0.018	-0.254	0.033	-0.090	0.179	0.352	-0.305	0.034	-0.113	0.042	-0.066	-0.122	ant at
	alcium	norganic hosphate	lucose	UN	ric	holesterol	otal rotein	1bumen	otal ilirubin	lkaline hosphatase	рн	GOT	ody Weight	де	- significant
	Inorg. Fhos. Glucose Glucose Total Protal Protal	Inorg. Phos. Choles-	LDH LOCAL TOCAL TOCA	-0.013 Calcium Calcium Calcium Uric Phos. Calcium Choles- Chol	-0.2½ -0.100 0.136	cium cium cium cium cium cium cium cium cose -0.018 0.014 cose -0.254 -0.100 0.136 cose c	ium Calcium Calcium Inorg. Choles. Choles.	ium Cal Inpo	inm Ca	tum in mine	tuum tuum tuum tuum tuum tuum tuum tuum	tum tum full fu	tum tium and the following th	tum tum tum color fig. col	tum itum i

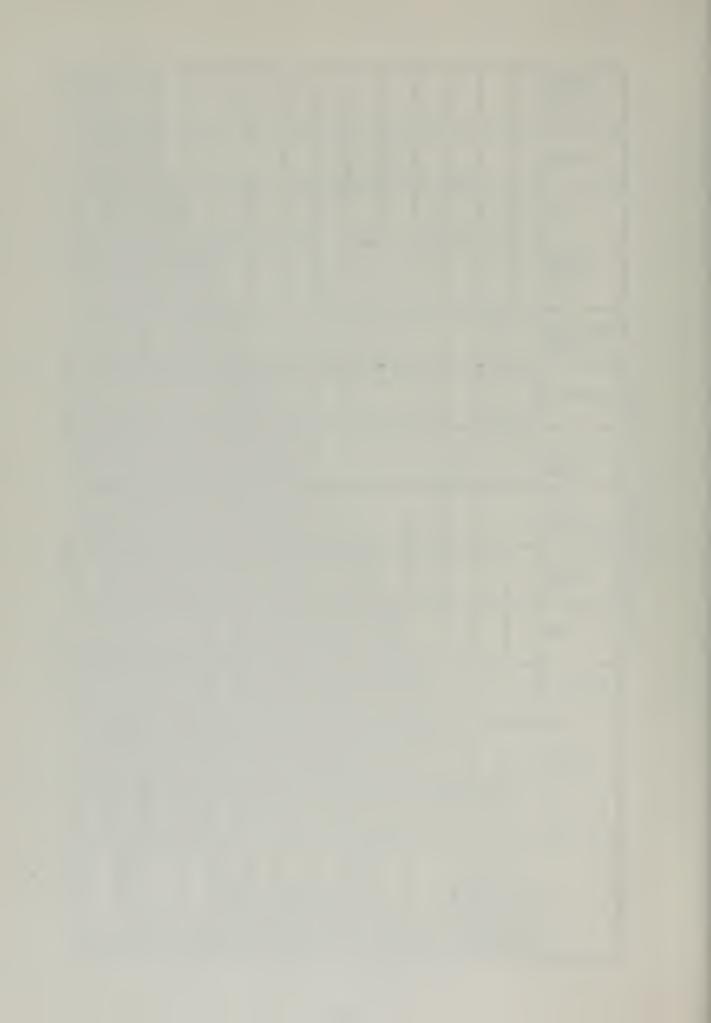


TABLE VI-B CORRELATION MATRIX - 30 CATS

Calcium Inorganic Phosphate Glucose BUN Uric Acid Cholesterol Total Protein Albumen Albumen Albumen Albumen Albumen SGOT BOdy Weight	-0.458 -0.458 -0.458 -0.458 -0.458 -0.458 -0.458 -0.171 -0.447 -0.468 -0.122 -0.289 -0.122	-0.184 -0.272 -0.278 -0.433 0.395 -0.363	0.128 0.197	0.482 0.015 0.015 0.016 -0.024 -0.026 -0.002	-0.354 0.092 -0.068	Choles- 10.039 0.230 0.374 0.226	Protein Protein 0.238 0.238 0.437	о. 0 о. 29 о о. 48 ж ж. 44	Phos0.194 -0.554 **		TODS	Meight Body
Age	0.602	-0.4	0.434	6	0.018	-0.133	0.514	0.333		0.4	-0.09	0.561
* - significant	at	$\alpha = 0.0$	5 (r;	소 ~ II	0.367);	₩ *	ignificant	cant at	$t \alpha = 0$.01(r.j.	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	0.470)



2. H_0 : The true coefficient of correlation, $\rho_{j,k}^m$, between variables j and k for the males is zero. This hypothesis is tested separately for horses and cats. The critical values of $r_{j,k}$ are presented in Table VII.

TABLE VII

CRITICAL VALUE OF $r_{j,k}$ FOR THE SPECIFIED α

N	$\alpha = 0.05$	$\alpha = 0.01$
23 (Male Horses)	0.413	0.526
15 (Male Cats)	0.514	0.641

Triangular matrices of sample correlation coefficients for the 23 male horses and 15 male cats are presented in Tables VIII-A and VIII-B respectively. Significant values are indicated as previously described.

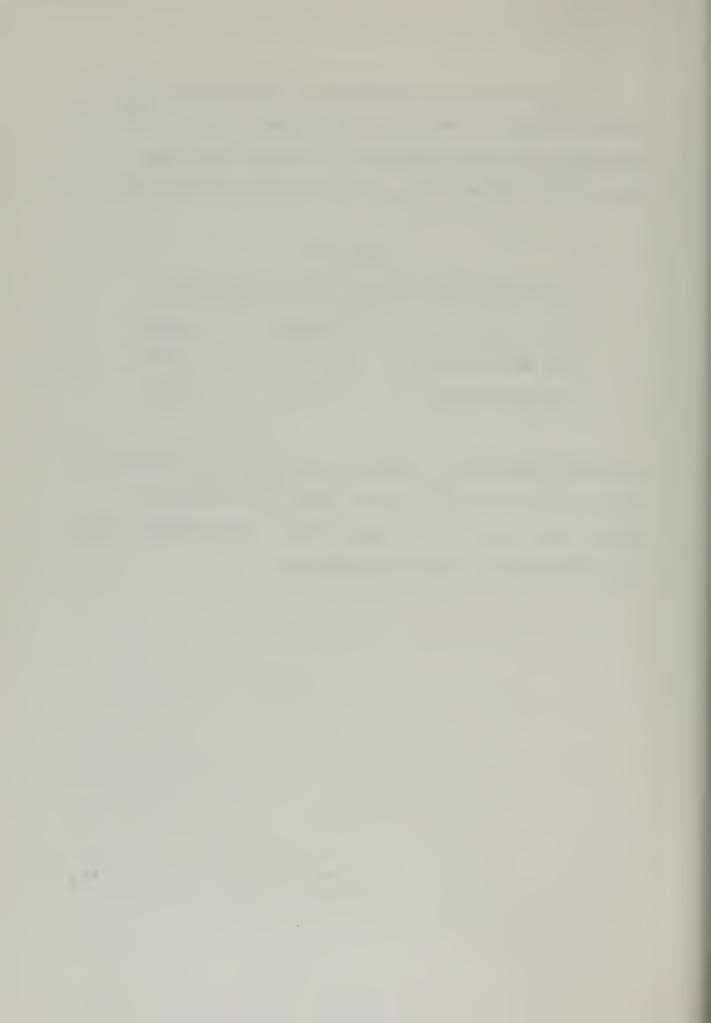


TABLE VIII-A CORRELATION MATRIX - MALE HORSES

			ااد	ORREDALION	- 11	MAINI	TUMP -	CICATON					
	muiols)	Inorg.	egncose	ВПИ	Uric	Choles-	Total Protein	и∋шлqГА	Total nidurilia	Phos.	грн	TODS	Body Weight
Calcium													
Inorganic	-0.035												
Glucose	-0.047	-0.254											
BUN	-0.124	-0.176	0.127										
Uric	0.178	0.229	0.132	-0.296									
Cholesterol	-0.051	0.341	0.246	-0.126	0.300								
Total	0.119	-0.610	0.301	0.075	0.216	980.0							
Albumen	0.512	0.187	-0.030	0.218	0.302	-0.032	-0.209						
Total Bilirubin	-0.472	0.025	0.113	-0.337	0.023	0.204	0.259	-0.825					
Alkaline Phosphatase	0.078	0.718	0.040	-0.216	0.155	0.523	-0.426	0.247	-0.167				
грн	0.005	0.359	-0.393	0.124	0.104	0.098	-0.289	0.151	-0.190	0.160			
SGOT	0.101	090.0	-0.043	0.037	-0.162	-0.225	-0.114	0.041	-0.040	-0.013	0.366	•	
Body Weight	-0.262	-0.578	-0.128	0.110	-0.301	1	0.441	-0.402	0.240	-0.644	-0.101	0.048	
Age	0.123	-0.611	0.195	-0.017	0.113	-0.472	0.503	980.0-	0.054	-0.456	-0.419	-0.172	960 • 0
* - significant	ant at	α = 0.	0.05 (r		0.41	3); **	1	significant	at	$\alpha = 0.01$	1 (rj,k	\\ \ \ \ \ \ \ \ \ \ \ \ \ \	526)

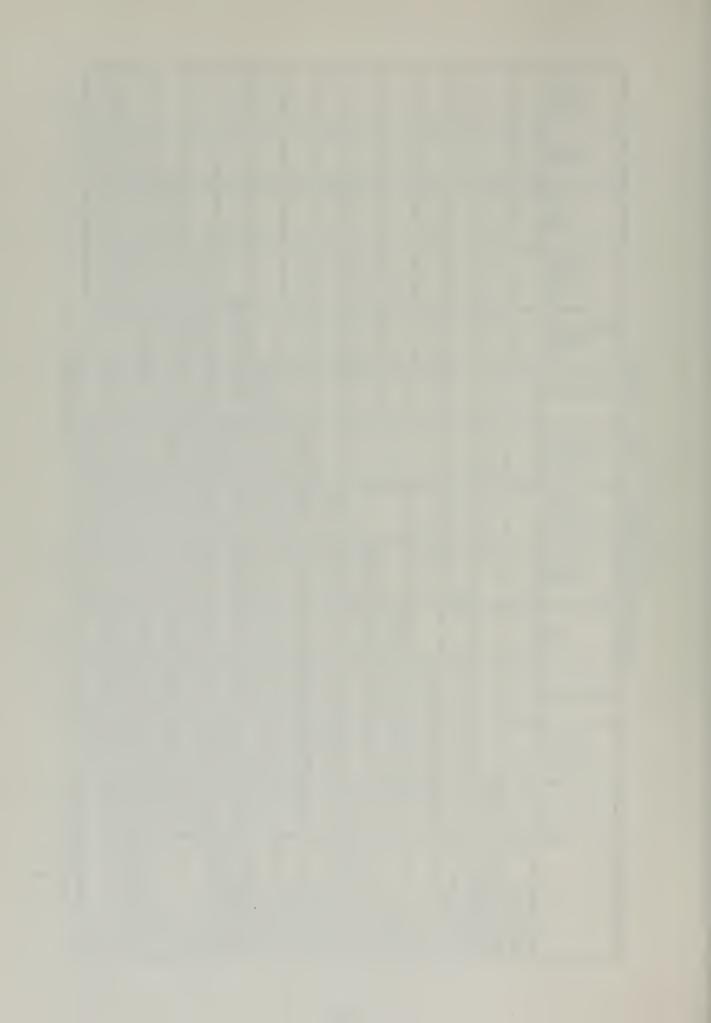
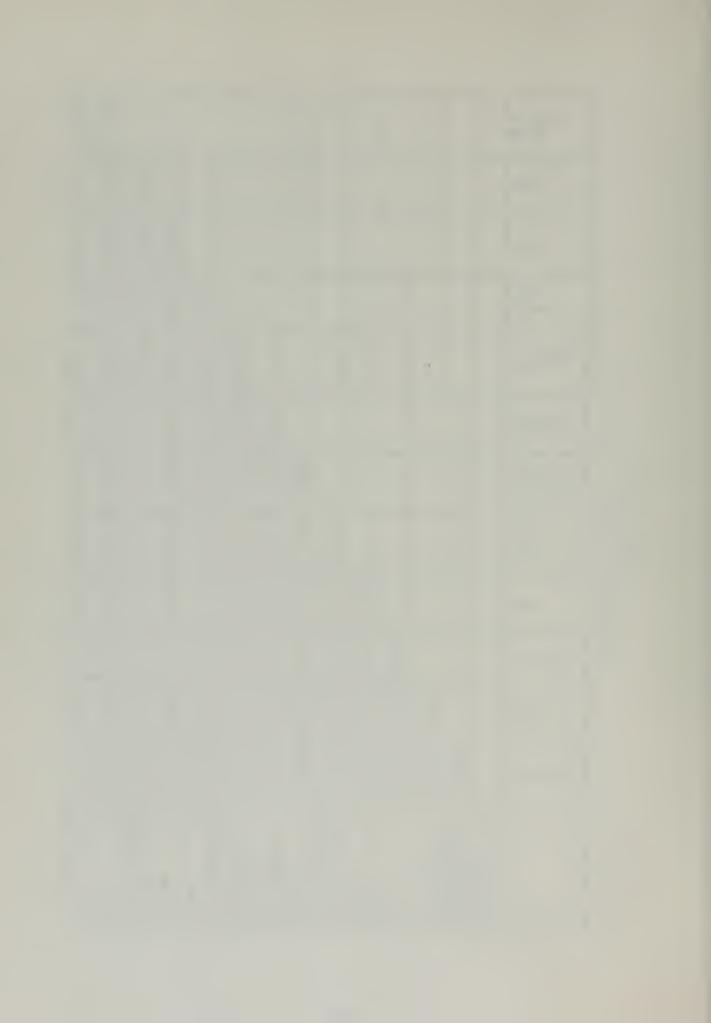


TABLE VIII-B
CORRELATION MATRIX - MALE CATS

Body Weight													0.629	> 0.641
LODS												0.350	-0.053	rj,k }
НДЛ											-0.014	-0.225	-0.424	.01 (
Phos.										0.399	-0.122	-0.768	-0.682	at $\alpha = 0$
иэшиdlA									-0.311	-0.223	0.631	0.666	0.363	
Total Protein								0.321	-0.650	-0.293	0.282	0.514	0.522	significant
choles-							0.006	0.278	890•0-	0.048	0.557	0.238	-0.123	1 * *
Uric Acid						-0,377	-0.017	-0.040	0.226	-0.159	-0.106	-0.314	-0.021	.514);
впи					0.548	-0.463	0.018	-0.211	-0.191	-0.262	-0.227	0.030	0.119	0 ^II
egncose			*	0.058	0.120	-0.148	0.121	0.216	-0.202	-0.490	0.112	0.306	0.574	(r,k
Inorg.			-0.455	-0.344	-0.132	0.454	-0.269	-0.073	0.516	0.514	0.267	-0.395	-0.508	$\alpha = 0.05$
- Calcium		0.739	-0.532		-0.048	0.411	-0.353	-0.111	0.480	0.446	0.112	-0.362	-0.638	at
	Calcium	Inorganic Phosphate	Glucose	BUN	Uric Acid	Cholesterol	Total Protein	Albumen	Alkaline Phosphatase	гон	SGOT	Body Weight	Age	* - significant



3. H_0 : The true correlation coefficient, $\rho_{j,k}^f$, between variables j and k for females is equal to zero. This hypothesis is tested separately for horses and cats. The critical values of $r_{j,k}$ are specified in Table IX.

	N		$\alpha = 0.05$	$\alpha = 0.01$
21	(Female	Horses)	0.433	0.549
15	(Female	Cats)	0.514	0.641

Triangular matrices of sample correlation coefficients for the 21 female horses and 15 female cats are presented in Tables X-A and X-B. Significance is indicated as previously specified.



TABLE X-A
CORRELATION MATRIX - FEMALE HORSES

Body Weight														0.473	0.549)
TODS													0.140	0.051	- ×, c
ГDH												-0.022	0.011	-0.346	01 (]
Phos.											0.295	-0.108	-0.665	-0.662	ت اا ع
LatoT niduriLia										-0.212	-0.238	0.289	0.203	0.154	at
иэшиqlA									-0.360	-0.111	0.159	0.134	-0.065	-0.242	significant
Total Protein								-0.256	0.613	-0.274	-0.362	0.027	0.238	0.184	। ਲ±ਲ
choles-							-0.390	0.254	-0.129	0.056	0.013	-0.149	-0.242	-0.123	** .(
Uric Acid						0.283	-0.534	0.669	-0.220	0.382	-0.253	0.166	-0.348	-0.461	0.433
вли					-0.125	-0.110	-0.266	-0.421	0.113	0.030	-0.042	0.206	-0.051	0.063], k ≥
esoonte				0.137	0.378	0.324	-0.506	0.057	-0.399	0.620	0.094	-0.217	-0.590	-0,517	0.05 (r
Inorg.			0.515	900.0-	0.448	0.274	-0.394	0.028	-0.241	0.852	0.425	-0.268	-0.524	-0.601	α = 0.
muioleO		-0.163	-0.0260	-0.470	-0.043	-0.056	0.210	0.162	-0.022	-0.024	-0.198	0.046	0.100	-0.349	int at
	Calcium	Inorganic Phosphate	Glucose	BUN	Uric Acid	Cholesterol	Total Protein	Albumen	Total Bilirubin	Alkaline Phosphatase	грн	SGOT	Body Weight	Age	- significant

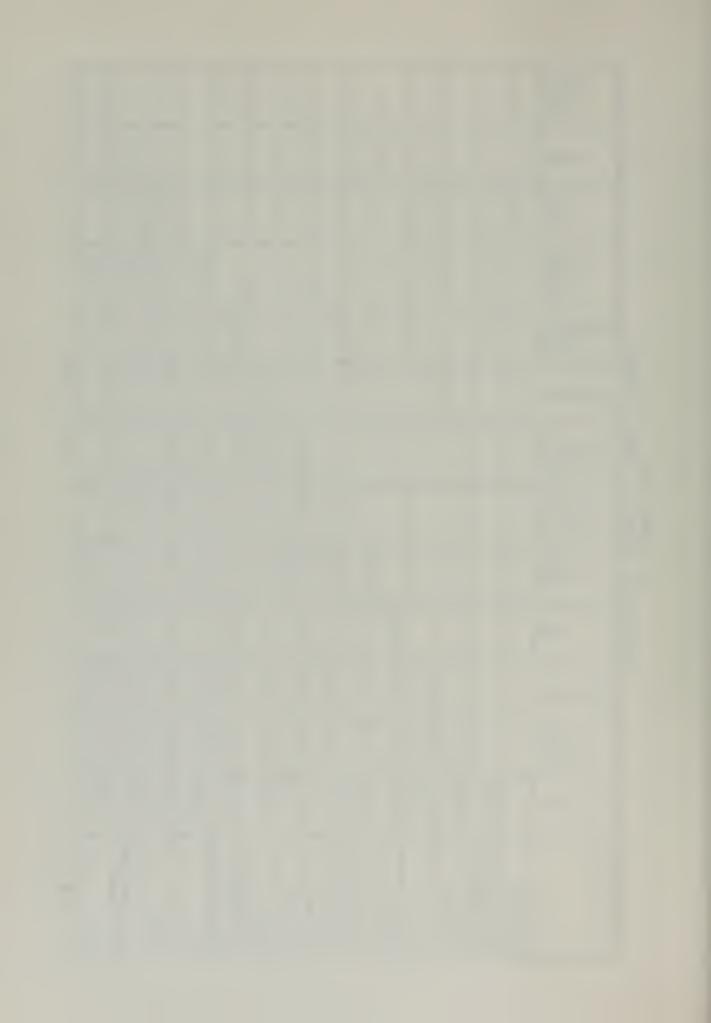
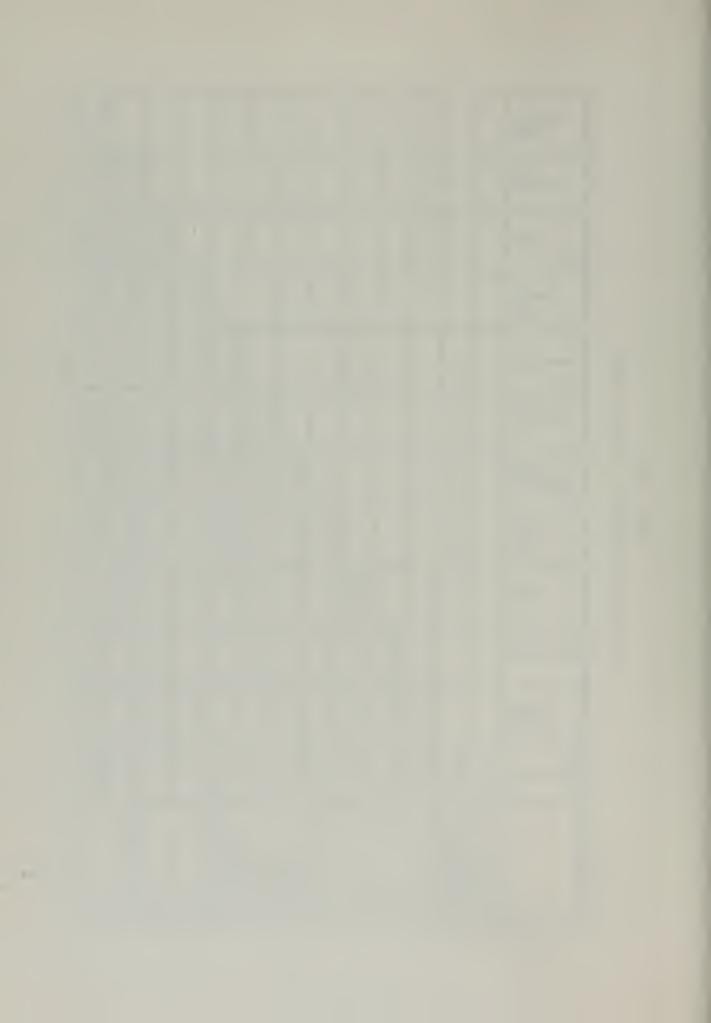


TABLE X-B
CORRELATION MATRIX - FEMALE CATS

Body Body													0.498
TODS												-0.079	-0.193
грн											0.305	-0.181	-0.545
ъров. Р1Ка.										-0.136	-0.324	-0.441	-0.282
иЭшпаТА									0.397	-0.450	-0.357	0.315	0.317
Total								0.091	-0.409	-0.279	0.333	0.545	0.638
choles-							0.124	0.197	-0.058	0.203	0.101	0.165	-0.192
Uric						-0.284	0.214	-0.278	-0.019	0.138	0.047	-0.201	0.098
впи					0.523	0.272	0.283	0.115	-0.206	0.106	0.175	-0.005	0.077
grncose				-0.077	0.060	-0.432	900.0	0.264	0.252	0.306	0.195	0.114	0.296
Inorg.			0.217	-0 269	0.120	0.059	-0.228	-0.277	0.355	0.198	0.488	-0.491	-0.502
- muislaD		0.398	-0.292	-0.122	-0.304	0.460	-0 •380	0.278	0.508	0.341	0.077	-0.332	-0.678
	Calcium	Inorganic	Glucose	BUN	Uric Acid	Cholesterol	Total Protein	Albumen	Alkaline Phosphatase	грн	SGOT	Body Weight	Age

*-significant at $\alpha = 0.05 \; (|r_{j,k}| \ge 0.514); \; **$ -significant at $\alpha = 0.01 \; (|r_{j,k}| \ge 0.641)$



4.
$$H_0: \rho_{j,k}^m = \rho_{j,k}^f = \rho_{j,k}$$

To test this hypothesis Fisher's Z transformation is employed where

$$z_{j,k}^{m} = \frac{1}{2} \ln \left[\frac{1 + r_{j,k}^{m}}{1 - r_{j,k}^{m}} \right]$$

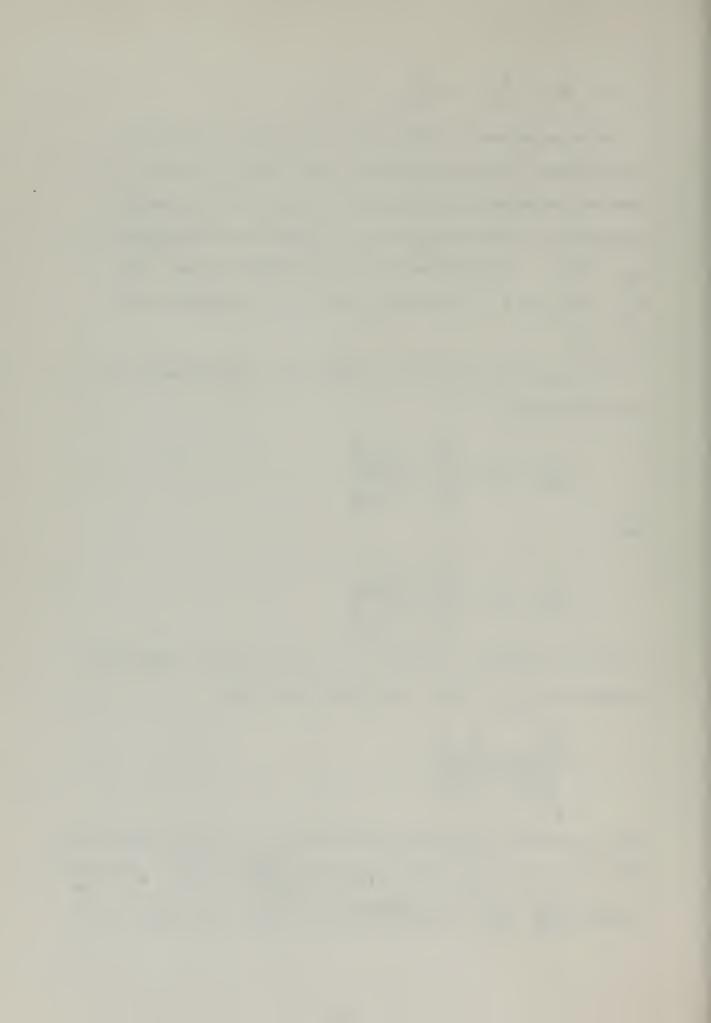
and

$$Z_{j,k}^{f} = \frac{1}{2} \ln \left[\frac{1 + r_{j,k}^{f}}{1 - r_{j,k}^{f}} \right]$$

It will be noted that each $z_{j,k}$ is the inverse hyperbolic tangent of $r_{j,k}$ [16]. If H_o is true, then

$$\frac{\left|z_{j,k}^{m} - z_{j,k}^{f}\right|}{\sqrt{\frac{1}{N^{m}-3} + \frac{1}{N^{f}-3}}}$$

has a standard normal distribution [17]. In the equine data, $N^{m}=23$ and $N^{f}=21$. The quantity $\sqrt{\frac{1}{N^{m}-3}+\frac{1}{N^{f}-3}}$ therefore becomes $\sqrt{\frac{1}{20}+\frac{1}{18}}\simeq \sqrt{0.10555...}\simeq 0.325$. To reject H_O at



the α = 0.05 level ($|z_{j,k}^{m} - z_{j,k}^{f}|$), must be greater than or equal to (1.96)(0.325) = 0.637. To reject H_o at the α = 0.01 level this absolute difference must be greater than or equal to (2.575)(0.325) = 0.837. It should be recalled that 1.96 and 2.575 represent the (1- α) = 0.95 and (1- α) = 0.99 percentile points of the standard normal distribution, respectively.

In the equine data, statistically significant differences between male and female sample correlation coefficients are presented in Table XI.

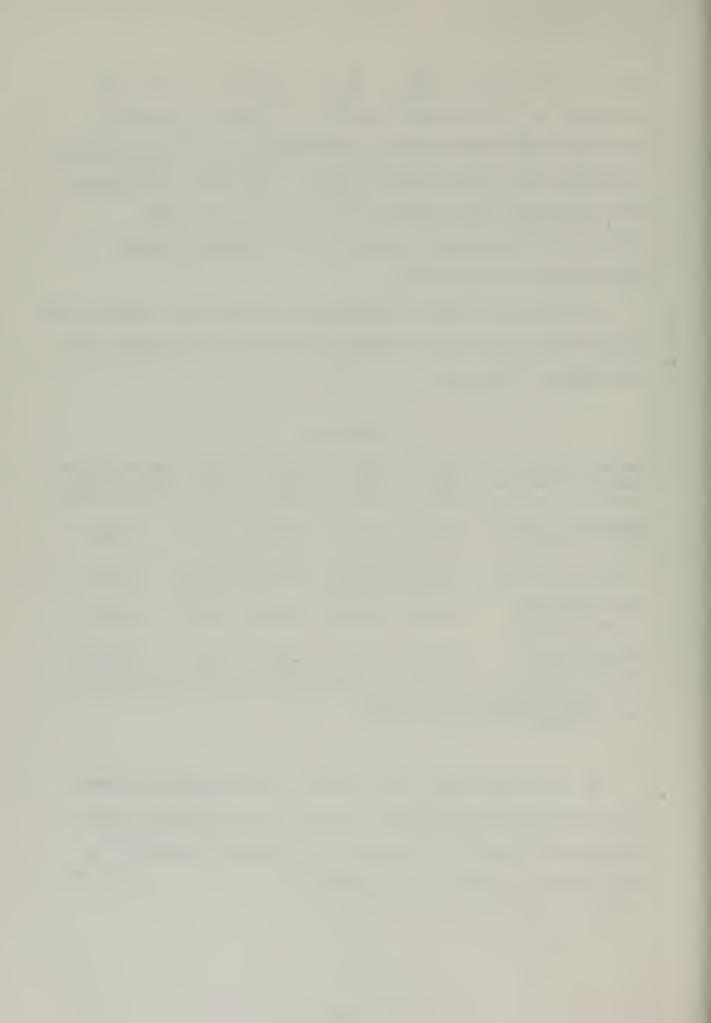
TABLE XI

Paired Variables	r ^m j,k	z ^m j,k	r ^f j,k	z ^f j,k	$ z_{j,k}^m - z_{j,k}^f $
Inorganic Phos- phate & Glucose	-0.254	-0.260	0.515	0.570	0.830*
Glucose and Age	0.195	-0.198	-0.517	-0.572	0.770*
Uric Acid and Total Protein	0.216	0.220	-0.534	-0.596	0.816*
Glucose and Total Protein	0.301	0.311	-0.506	-0.557	0.868**

^{* -} significant at $\alpha = 0.05$

In the feline data there were no statistically significant differences between any of the male and female correlation coefficients. Therefore, H_{O} cannot be rejected in the case of the cat, at α = 0.05.

^{** -} significant at $\alpha = 0.01$



5. H_0 : $\underline{\mu}^m - \underline{\mu}^f = 0$; that is, the sample mean vector for males and the sample mean vector for females came from the same parent population with mean vector $\underline{\mu}$. To test the validity of H_0 , Mahalanobis' D^2 statistic is computed as follows:

$$[\bar{\mathbf{x}}^{\mathrm{m}} - \bar{\mathbf{x}}^{\mathrm{f}}]^{\mathrm{T}} \quad s^{-1}[\bar{\mathbf{x}}^{\mathrm{m}} - \bar{\mathbf{x}}^{\mathrm{f}}] = D^{2}$$

where $[\bar{x}^m - \bar{x}^f]^T$ is the transpose of the 14 by 1 vector of the arithmetic difference between the male and female vectors of sample means, S^{-1} is the inverse of the pooled variance-covariance matrix S,

where
$$S = \frac{(N^{m}-1)S^{m} + (N^{f}-1)S^{f}}{N^{m} + N^{f} - 2}$$

and S^m is the variance-covariance matrix for male data S^f is the variance-covariance matrix for female data N^m is the male sample size N^f is the female sample size.

If H_0 is true, then $D^2 \left[\frac{N^m N^f (N^m + N^f - p - 1)}{p (N^m + N^f) (N^m + N^f - 2)} \right]$ is distributed in accordance with the F distribution that has $(p, N^m + N^f - p - 1)$ degrees of freedom [18]. The results of this hypothesis test are presented in Table XII.

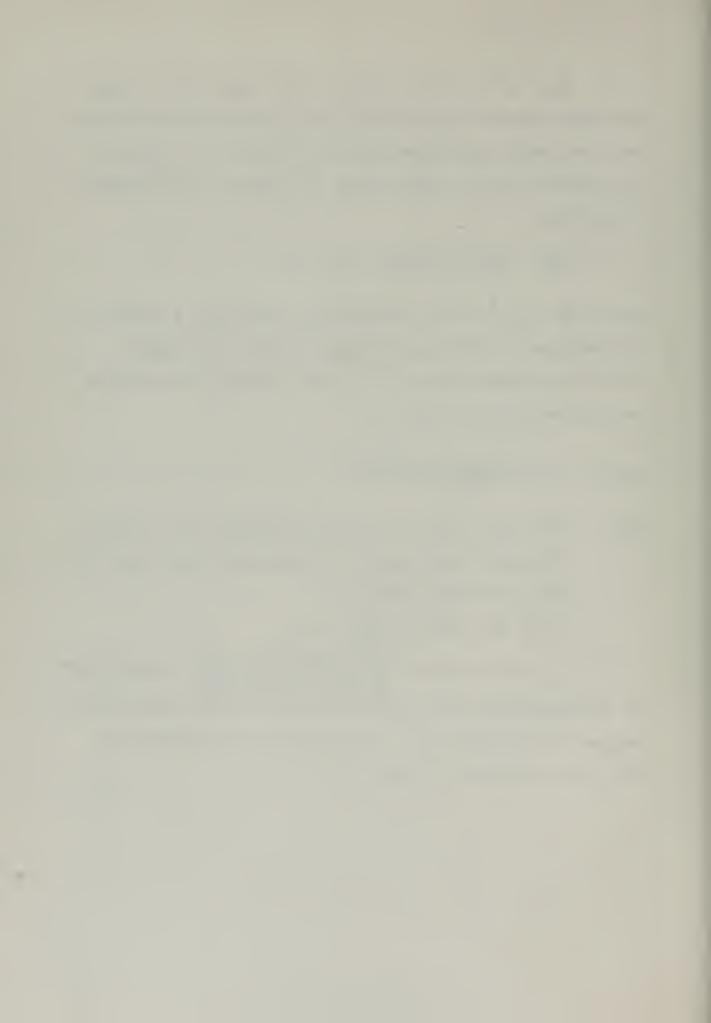
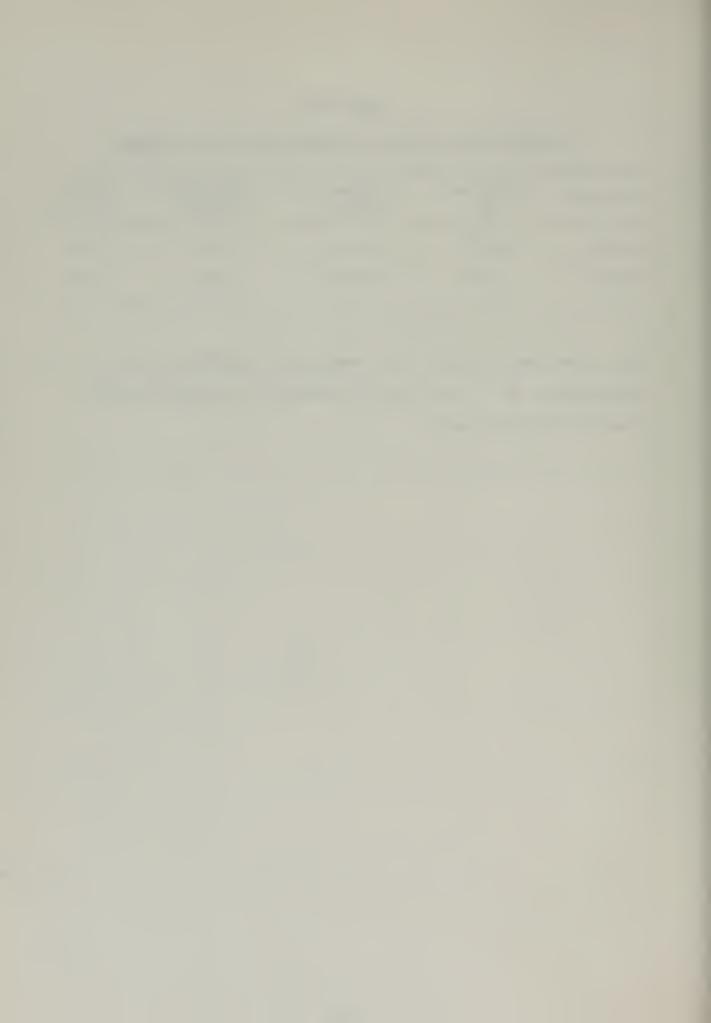


TABLE XII

DISCRIMINANT ANALYSIS BETWEEN MALES AND FEMALES

Species	Computed D2	Degrees of Freedom	Computed F Value	F at $\alpha = 0.05$
Equine	2.537	(14,29)	1.374	2.10
Feline	5.748	(13,16)	1.895	2.40

Thus, for each species, the computed F statistic is not significant at α = 0.05 and H $_{\odot}$ cannot be rejected at that level of significance.

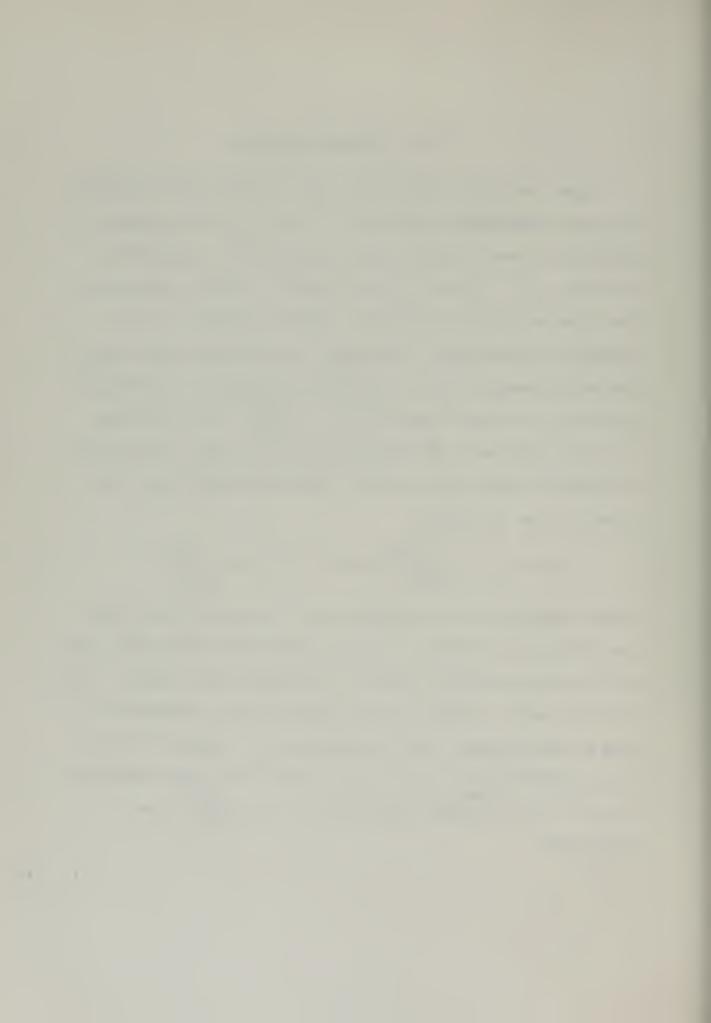


VII. TOLERANCE LIMITS

Upper and lower tolerance levels based on the observed data are determined as follows: each \bar{x} . j is estimating a population mean, μ_j ; each s_j^2 is estimating a population variance, σ_j^2 . μ_j and σ_j^2 are fixed but unknown parameters. The statistics \bar{x} . j and s_j^2 are random variables. It is possible to determine a constant, K, such that in a large series of samples from a normal distribution, a fixed proportion, γ , of the intervals \bar{x} . j $\pm K_{\alpha}\sqrt{s_j^2}$ will include $100 \ (1-\alpha)$ % or more of the distribution. Thus, statistical tolerance limits for a normal random variable, $X_{i,j}$, are given by the following:

$$L = \bar{x}_{ij} - K_{\alpha} \sqrt{s_{j}^{2}}$$
 and $U = \bar{x}_{ij} + K_{\alpha} \sqrt{s_{j}^{2}}$

These limits have the property that the probability that the interval includes at least a specified proportion $(1-\alpha)$ of the distribution is equal to a preassigned value α [19]. In this paper, values of 0.95 and 0.05 were assigned to γ and α respectively. The following $K_{0.05}$ values such that the probability is 0.95 that at least 95% of the distribution will be included between \bar{x} . $\pm K_{0.05} \sqrt{s_j^2}$ are presented:



N 44	$\frac{K_{0.05}}{2.415}$
38	2.464
30	2.549
24	2.651
21	2.723

These values are employed in constructing the tolerance limits for the biochemical components of each species.

These limits are presented in Tables XIII-A and XIII-B.

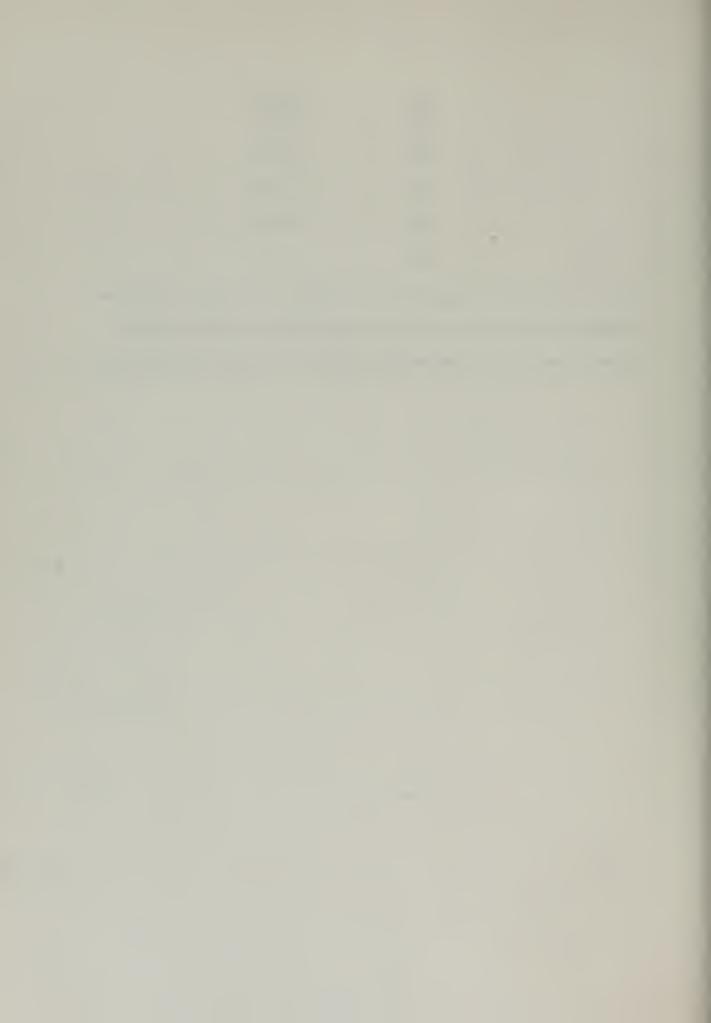


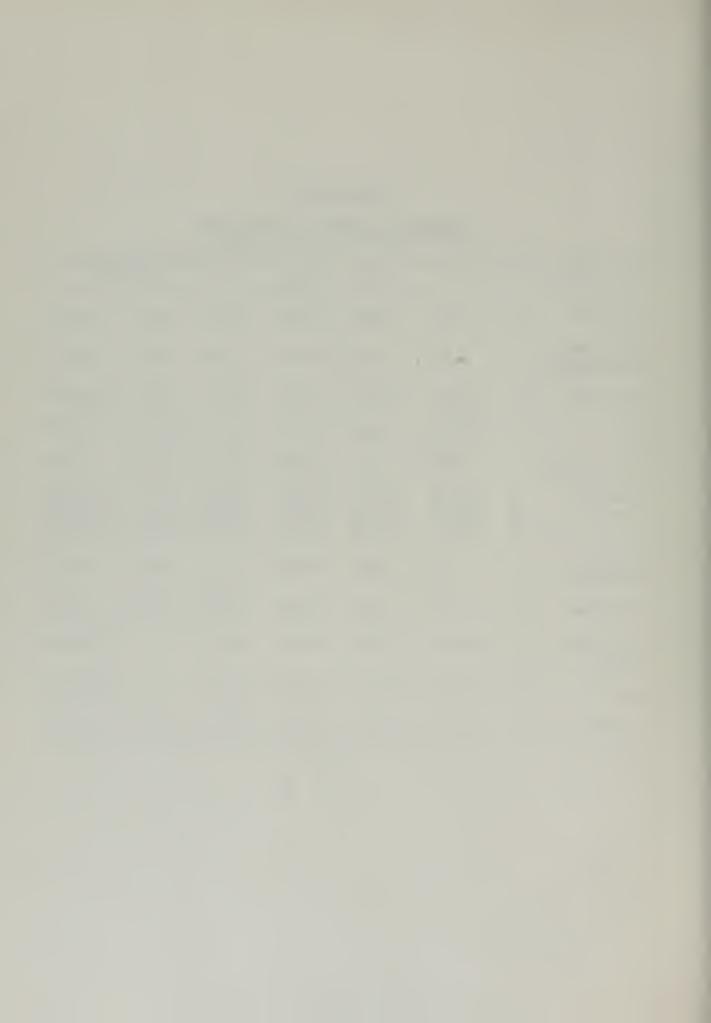
TABLE XIII-A
TOLERANCE LIMITS IN THE HORSE

Biochemical Component	N	₹·j	sj	K. ₀₅	x.j ± K. ₀₅ S
Calcium	44	11.78	0.61	2.415	10.31 - 13.25
Inorganic Phosphate	44	3.62	0.92	2.415	1.40 - 5.84
Glucose	44	86.77	12.47	2.415	56.65 - 116.89
BUN	44	14.55	3.72	2.415	5.57 - 23.53
Uric Acid	44	0.45	0.15	2.415	0.09 - 0.81
Cholesterol	44	112.70	15.31	2.415	75.73 - 149.67
Total Protein	44	6.49	0.40	2.415	5.52 - 7.46
Albumen	44	0.48	0.09	2.415	0.26 - 0.70
Total Bilirubin	44	1.40	0.90	2.415	0 - 3.57
Alkaline Phosphatase	44	145.39	77 . 39	2.415	0 - 332.29
LDH	44	223.57	67.51	2.415	60.53 - 386.61
SGOT	44 38	786.36 636 05	433.77 127.80	2.464	321.15 - 950.95



TABLE XIII-B
TOLERANCE LIMITS IN THE CAT

Variable	N	x	S	к. ₀₅	KS	x ± KS
Calcium	30	9.27	0.81	2.549	2.06	7.21 - 11.33
Inorganic Phosphate	30	7.23	1.13	2.549	2.88	4.35 - 10.11
Glucose	30	78.53	27.35	2.549	69.72	8.81 - 148.25
BUN	30	25.50	5.01	2.549	12.77	12.73 - 38.27
Uric Acid	30	0.90	0.16	2.549	0.41	0.49 - 1.31
Choles- terol	30 24 21	79.60 91.79 97.33	36.64 29.91 27.76	2.549 2.651 2.723	93.40 79.29 75.59	0 - 173.00 12.50 - 171.08 21.74 - 172.92
Total Protein	30	6.78	0.52	2.549	1.33	5.45 - 8.11
Albumen	30	1.53	0.18	2.549	0.46	1.07 - 1.99
Alkaline Phos.	30	60.67	30.86	2.549	78.66	0 - 139.33
LDH	30	271.03	121.49	2.549	309.68	0 - 580.71
SGOT	30	86.37	32.35	2.549	82.46	3.91 - 168.83



VIII. SUMMARY

A summary of the significant findings of this study will be presented according to species. In this summary, "significant," as applied to sample correlation coefficients, refers to an ability to reject H_0 : $\rho_{j,k} = 0$ at $\alpha \le 0.05$.

A. EQUINE DATA

In the case of the data pertaining to the 44 horses, significant positive correlation coefficients were obtained for the 23 males in the following pair-wise observa ions:

Calcium and Albumen
Inorganic Phosphate and Alkaline Phosphatase
Cholesterol and Alkaline Phosphatase
Total Protein and Body Weight
Total Protein and Age

Significant negative correlation coefficients for the 23 male horses were obtained in the following paired observations:

Calcium and Total Bilirubin

Inorganic Phosphate and Total Protein

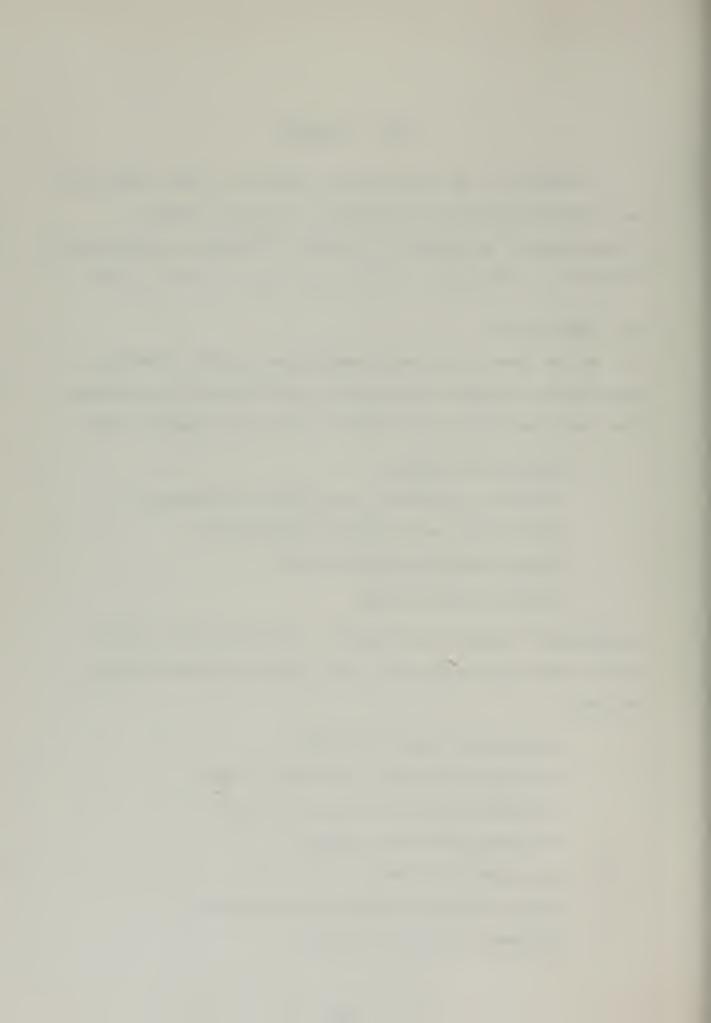
Inorganic Phosphate and Body Weight

Inorganic Phosphate and Age

Cholesterol and Age

Total Protein and Alkaline Phosphatase

Albumen and Total Bilirubin



Alkaline Phosphatase and Body Weight
Alkaline Phosphatase and Age
LDH and Age

Significant positive correlation coefficients were observed in the sample of 21 female horses between the following paired variables:

*Inorganic Phosphate and Glucose
Inorganic Phosphate and Uric Acid
Inorganic Phosphate and Alkaline Phosphatase
Glucose and Alkaline Phosphatase
Uric Acid and Albumen
Total Protein and Total Bilirubin
Body Weight and Age

Significant negative correlation coefficients were observed in the sample of 21 female horses between the following paired variables:

Calcium and BUN

Inorganic Phosphate and Body Weight

Inorganic Phosphate and Age

Glucose and Body Weight

*Glucose and Age

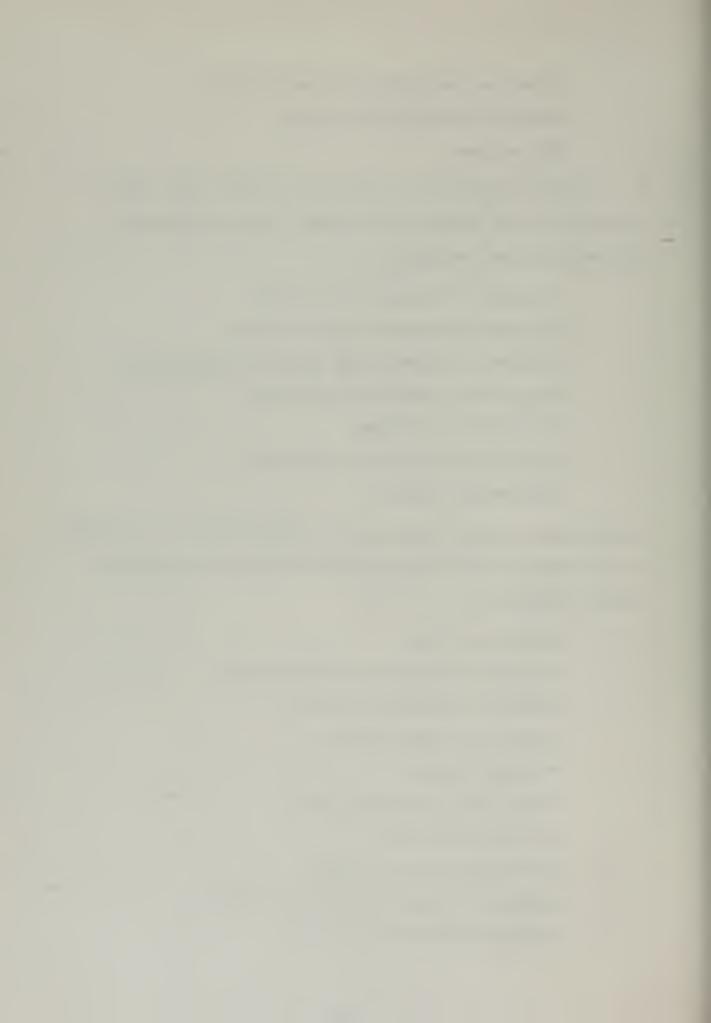
*Uric Acid and Total Protein

Uric Acid and Age

Glucose and Total Protein

Alkaline Phosphatase and Body Weight

Alkaline Phosphatase and Age



Those correlation coefficients in the female found to be significantly different from the corresponding correlation coefficient in the male are indicated with a *.

Significant positive correlation coefficients in all 44 horses as a group that were not significant in either of the sub-groups considered separately were observed between the following paired variables:

Inorganic Phosphate and Cholesterol
Uric Acid and Cholesterol
Inorganic Phosphate and LDH

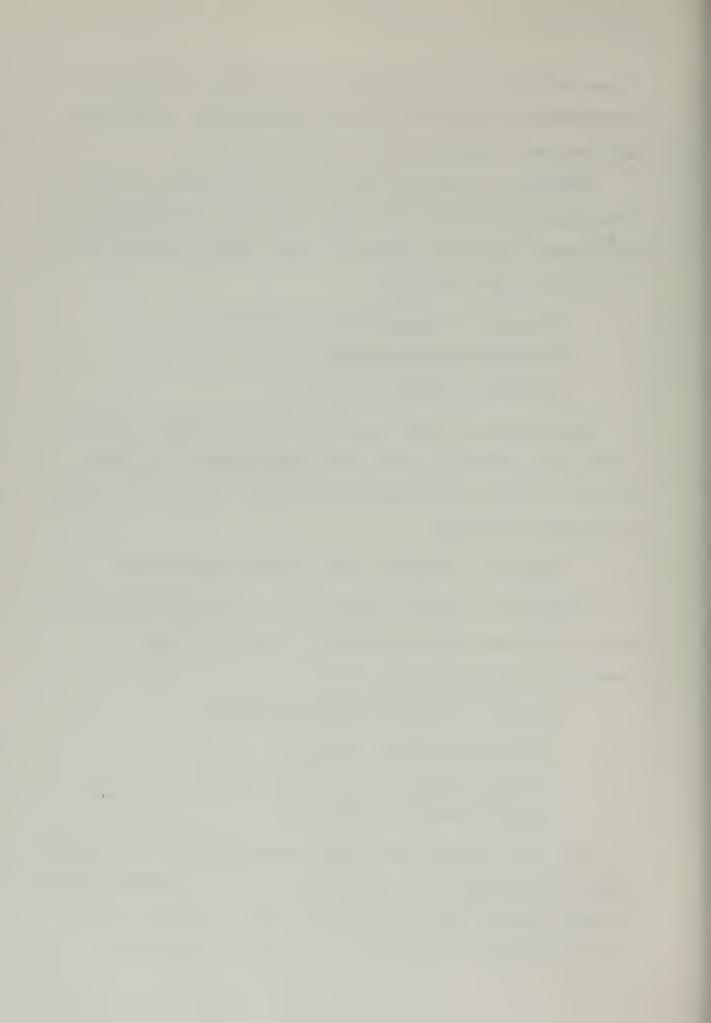
Significant positive correlation coefficients in all 44 horses as a group that were also significant in both the male and female sub-groups were observed between the following paired variables:

Inorganic Phosphate and Alkaline Phosphatase

Significant negative correlation coefficients in all 44 horses that were also significant in both the male and female sub-groups are as follows:

Inorganic Phosphate and Body Weight
Inorganic Phosphate and Age
Alkaline Phosphatase and Body Weight
Alkaline Phosphatase and Age

All other positive and negative correlation coefficients that were observed to be significant in all 44 horses appear to have reached significant levels only because of a very high correlation coefficient in one of the sub-groups.



In considering the fifth hypothesis, it is concluded from this study that there is no difference between male and female with respect to the mean values of the 12 serum biochemical parameters as reported by the autoanalyzer in the population of horses from which this sample of 44 horses is a representative sample.

B. FELINE DATA

With respect to 15 female cats, the following positive bivariate correlation coefficients were found to be significant:

BUN and Uric Acid

Total Protein and Body Weight

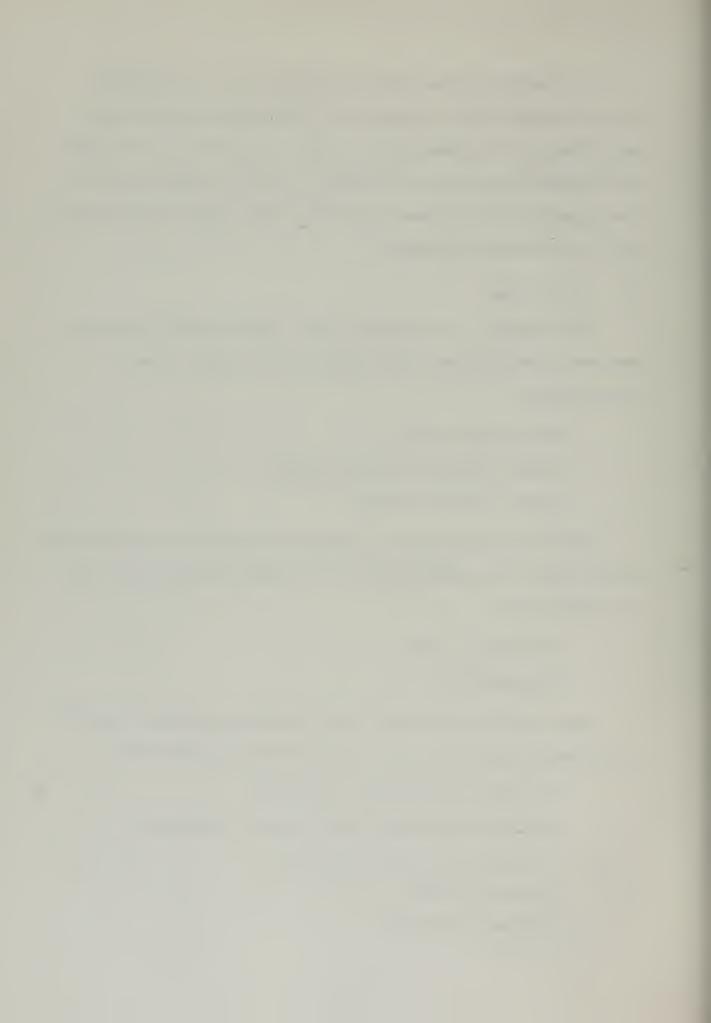
Total Protein and Age

The following negative bivariate correlation coefficients were found to be significant in the data obtained from the 15 female cats:

Calcium and Age

The 15 male cats showed the following positive correlation coefficients that were statistically significant:

Calcium and Inorganic Phosphate
Inorganic Phosphate and Alkaline Phosphatase
Inorganic Phosphate and LDH
Glucose and Age
BUN and Uric Acid



Cholesterol and SGOT

Total Protein and Age

Albumen and Body Weight

Body Weight and Age

The following statistically significant bivariate correlation coefficients were demonstrated from the male data:

Calcium and Glucose

Total Protein and Alkaline Phosphatase

Alkaline Phosphatase and Body Weight

Alkaline Phosphatase and Age

None of the correlation coefficients in one sex differed significantly from the corresponding coefficient in the other sex. Admittedly, the relatively small size of the sub-groups is a limiting factor.

The influence of the number of observations on the significance of correlation coefficients is evidenced when we consider the 30 cats as a single group. Significant positive correlation coefficients in all 30 cats were obtained for the following paired variables:

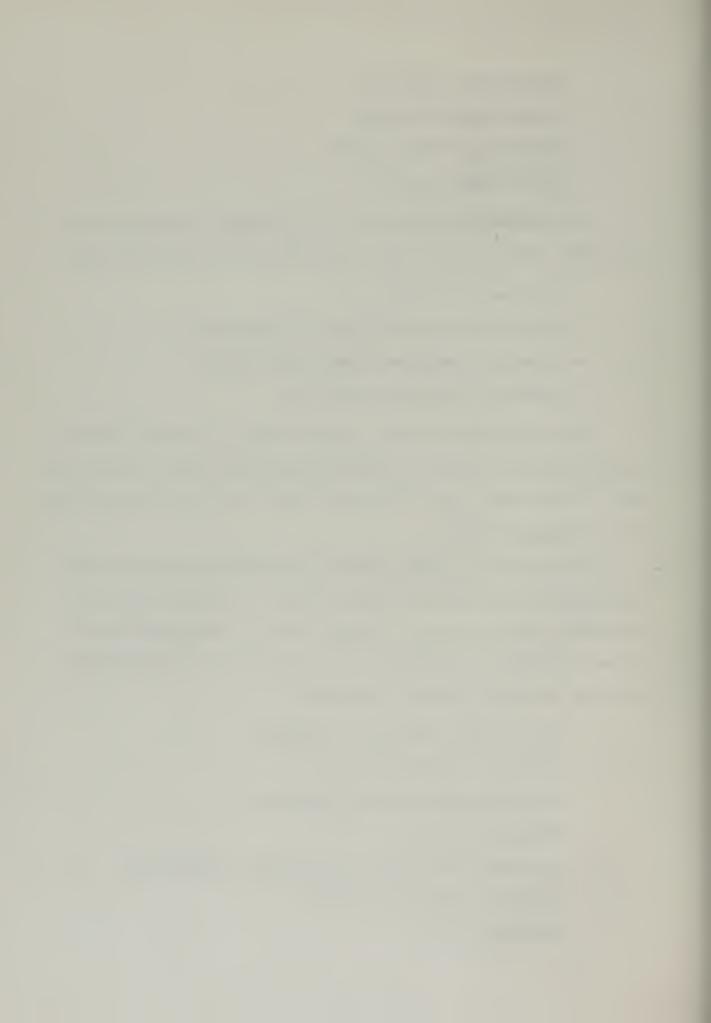
Calcium and Inorganic Phosphate

*Calcium and Cholesterol

*Calcium and Alkaline Phosphatase

*Calcium and LDH

Inorganic Phosphate and Alkaline Phosphatase
Inorganic Phosphate and LDH
Glucose and Age



BUN and Uric Acid

Cholesterol and SGOT

*Total Protein and Body Weight

Total Protein and Age

Albumen and Body Weight

Body Weight and Age

The following significant negative correlation coefficients between paired variables were observed in the 30 cats:

Calcium and Glucose
*Calcium and Total Protein

Calcium and Age

*Inorganic Phosphate and Body Weight

*Inorganic Phosphate and Age

Glucose and LDH

Total Protein and Alkaline Phosphatase

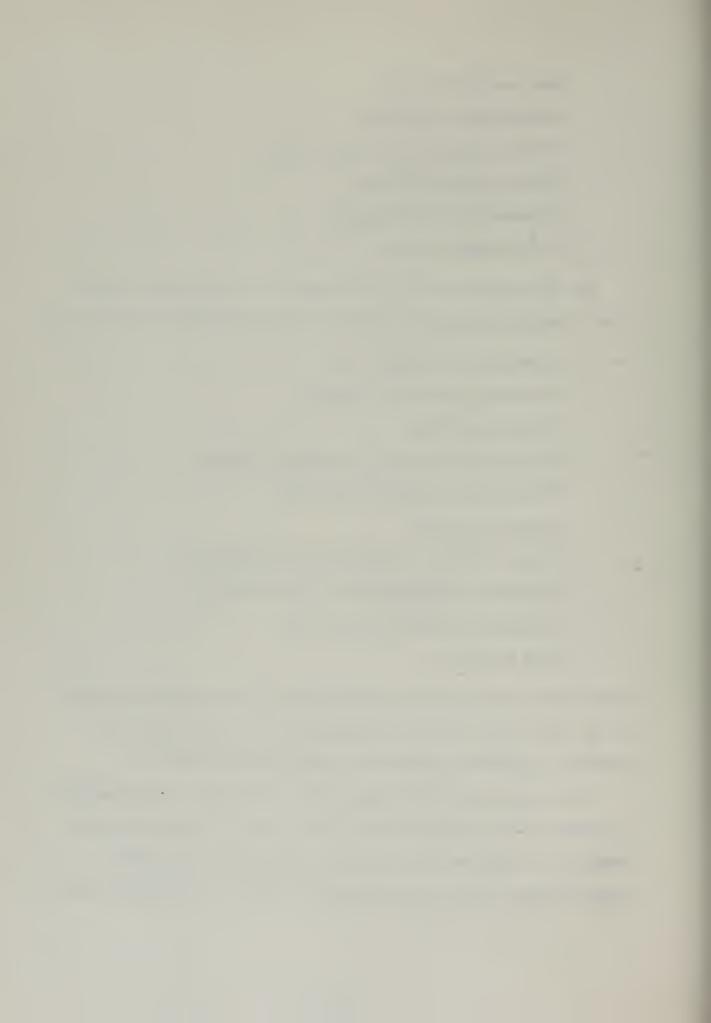
Alkaline Phosphatase and Body Weight

Alkaline Phosphatase and Age

LDH and Age

Significant correlation coefficient in the combined sample of 30 cats that were not significant in either males or females considered separately are indicated with a *.

Certainly, it would appear that additional observations in both male and female cats could result in an increased number of bivariate correlation coefficients attaining significance; this is particularly true of the female group.



With respect to the fifth hypothesis of equality of the mean vectors, it is concluded that there is no difference between males and females in the means of the 12 biochemical components in the feline population from which this sample of 30 is representative.

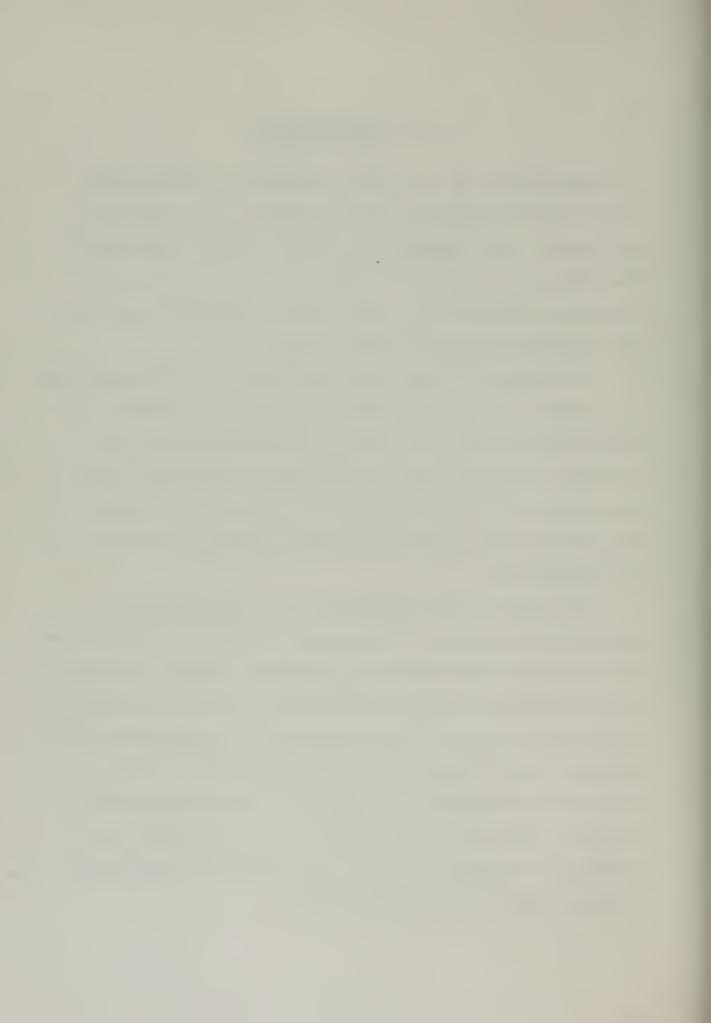


IX. RECOMMENDATIONS

The analysis of the equine biochemical data suggests future work is desirable, particularly in the measurement of albumen, LDH, and SGOT as reported by the autoanalyzer. The significant bivariate correlation coefficients, particularly as they occur in the female, should be exploited for possible diagnostic significance.

The analysis of the feline biochemical data demonstrates that animals in apparent robust health can nonetheless be hypercholesterolemic, at least as reported by the auto-analyzer. Even when the 9 most extreme cases were ignored the lower limit of the cholesterol tolerance was considerably below those values previously reported by Cornelius and Kaneko [20].

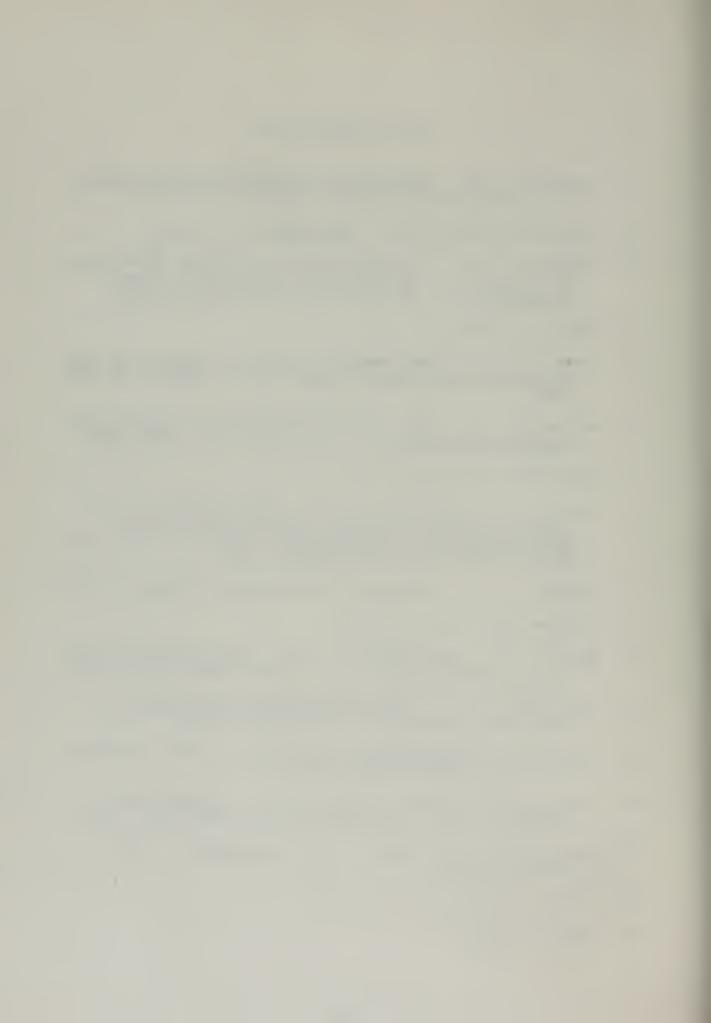
This work has been undertaken as a pilot study in multivariate analysis of biochemical components of the serum of two of the common species of domestic animals. Emphasis has been placed on tolerance interval estimations, possibly significant bivariate linear association as measured by the Pearson Product Moment Correlation Coefficient, and a discriminant analysis of the male and female sample mean vectors. With the increased use of the autoanalyzer and increased availability of data, this method of statistical analysis can and should be expanded.



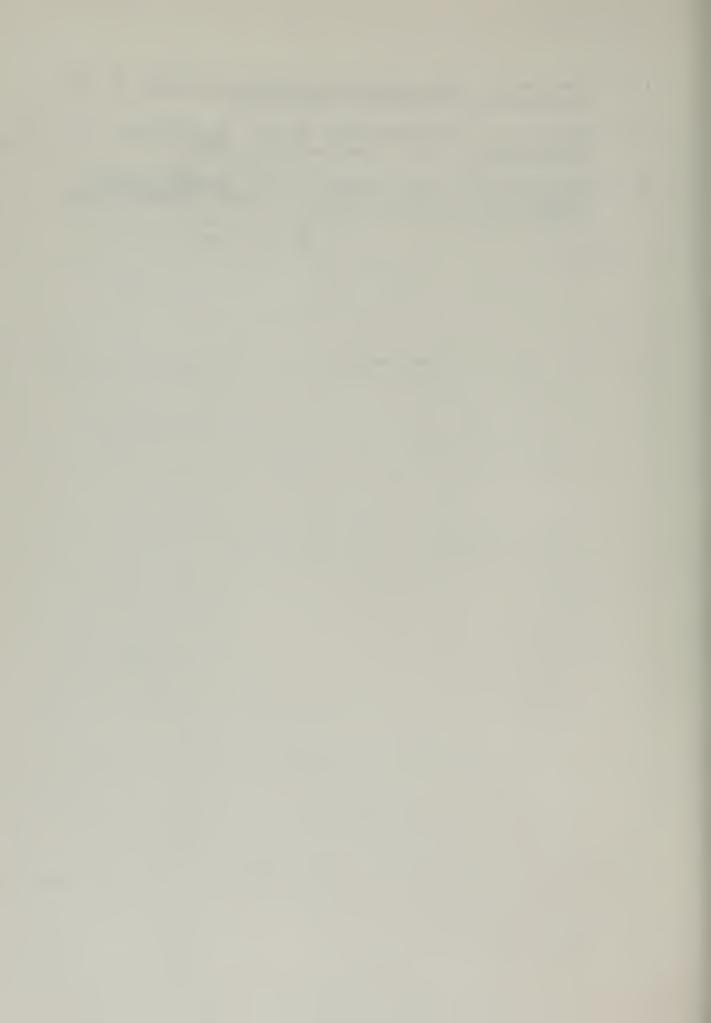
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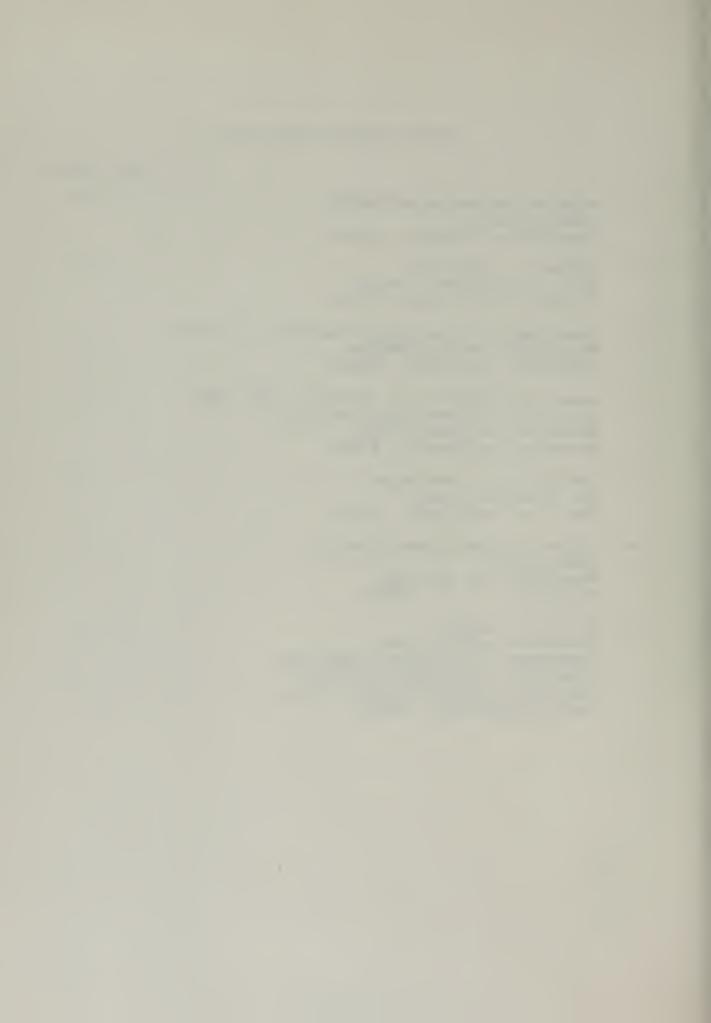


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Naval Postgraduate School Monterey, California 93940 Unclassified

2b. GROUP

3 REPORT TITLE

A MULTIVARIATE ANALYSIS OF CERTAIN BIOCHEMICAL COMPONENTS OF EQUINE AND FELINE SERUM SAMPLES AS REPORTED BY AN AUTO-ANALYZER SYSTEM

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Master's Thesis; March 1971

5. AUTHORISI (First name, middle initial, last name)

Robert Rothnick Jorgensen, Sr.; Lieutenant Colonel, United States Army

6. REPORT DATE
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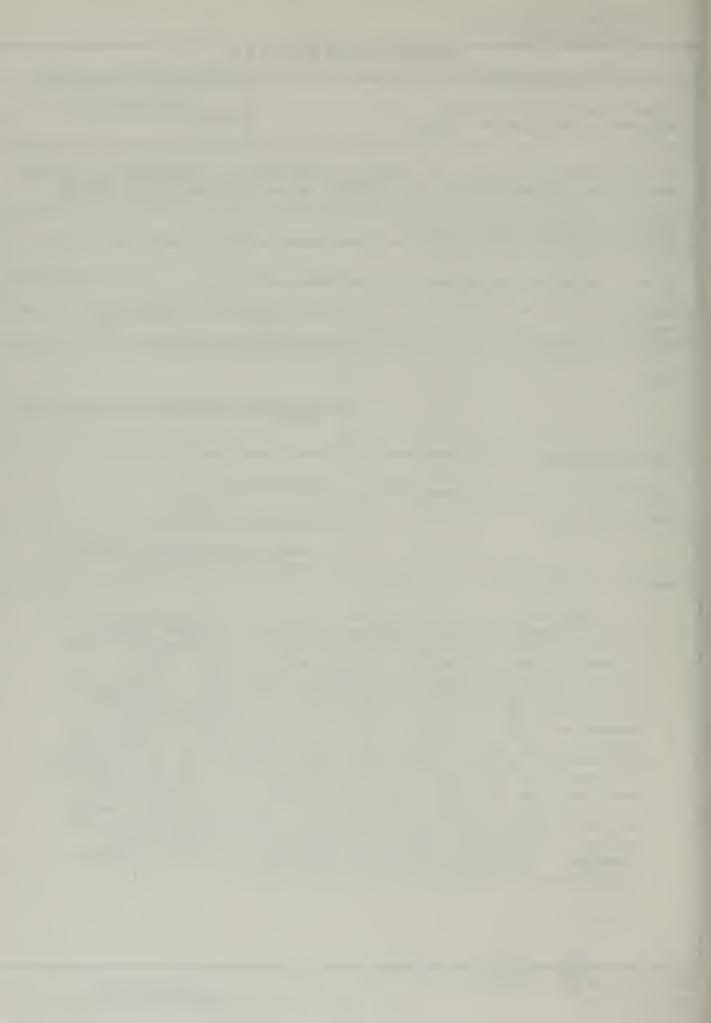
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13. ABSTRACT

This thesis contains a multivariate statistical analysis of the results of an automated analysis of serum samples from the horse and cat. In the horse, 12 biochemical components plus body weight and age are recorded; thus, observations are made on 14 random variables. In the case of the cat there are observations on 13 random variables. Ninety-one (91) pair-wise correlation coefficients are computed from the equine data and 78 pair-wise correlation coefficients are computed from the feline data. Extensive hypothesis testing concerning these correlation coefficients is conducted and the results are presented. A discriminant analysis for 2 groups, male and female, is conducted for each species. In this analysis the vector of sample means of the biochemical components plus body weight and age for males is contrasted with the corresponding vector from Tolerance limits for each biochemical component females. measured are presented for both species.

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